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# NAVAL POSTGRADUATE SCHOOL

## Monterey, California



HP-41C PROGRAMS AND INSTRUCTIONS

FOR

PROBABILITY AND STATISTICS

by

Peter W. Zehna

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## INTRODUCTION

The purpose of this report is to make available a set of programs and the corresponding user instructions so that the problem material found in the writer's textbooks, "Probability by Calculator and Statistics by Calculator" (hereafter referred to, respectively, as ZP and ZS) may be resolved using the HP-41C calculator. In particular, this means that courses using those textbooks, written entirely around the TI-59, need no longer be restricted to that particular machine as a prerequisite. It is almost essential, however, that the HP user have in his or her possession either the HP-41CV, or the HP-41C with the quad memory module installed, along with a card reader for recording magnetic cards. Also, as with the TI-59, it will be necessary to insert the HP applications module STAT PAC for use with the programs in ZS. No additional module is required for ZP.

The original intention was to write the HP programs in such a way that the TI user instructions could be used with little or no modification. That program was about 90% successful so that, in general, storage in various registers are identical as are the main subroutines labeled with user defined keys (with HP a,b,c, etc., replacing TI A', B', C', etc. in a natural way). There are, however, some special problems created by the differences in the two machines (RPN not being one of them, by the way) that made it impossible to be 100% successful in that endeavor. For example, the TI random number generator could not be duplicated in the HP because of the difference in accuracy of the two machines. Since the TI carries more significant figures internally than the HP, and that internal carriage is used to generate successive seeds for repeated applications, the two machines soon differ in their output. For true applications of random number generation that would be insignificant, even a desirable difference perhaps, but for tutorial purposes, which is the main intent of the books, that makes it impossible to verify answers and that is a serious drawback for the learner. Otherwise, the difference in accuracy created no special problems. The FIX 4 format is used in all of the HP output to follow and it will be found that the corresponding answers then agree to within 4 decimal places (the maximum usually presented in ZP and ZS) of the published answers given in the two books, almost without exception.

Writing the HP programs to utilize essentially the same user instructions as the TI meant not being able to take full advantage of the superior alpha-numerics and prompting facility of the HP41-C. The user may well want to adjust the programs presented here to take better advantage of that option but should of course adjust the user instructions accordingly. That particular feature in itself creates some special problems with regard to the use of HP applications modules like STAT PAC. Almost all of the programs in that module contain pauses for prompts from the user. Unfortunately, when such programs are called as subroutines within a calculator program, there is no automatic return from the module program to the parent one. Much of the success of the TI programs depended on precisely this feature utilizing the canned programs available in the master module for ZP and the statistics module for ZS. This made it necessary to replace several of the programs in the HP STAT PAC that would otherwise have been used, as well as to supply several key programs, such as the t and F distributions, that were missing. Fortunately, the massive memory capability furnished by the HP quad memory made it possible to furnish these and still have enough room for the main programs of interest. For ZS then, a special program called ZSTAT has been supplied for which there

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\*Prentice-Hall, Inc., Englewood Cliffs, NJ, 1982



is no direct TI analogue. The reader may view this as simply an addition to the HP STAT PAC in order to bring it more in line with the TI statistics module utilized throughout ZS.

In order to follow the textbooks as closely as possible with the least amount of cross-referencing, the following format will be followed. Starting with ZP, each chapter or section for which a separate program exists will be discussed separately starting on a new page. After pointing out any general differences that may exist for that chapter or section including the illustrative examples contained therein, the HP version of the User Instructions for that program will be added, together with a set of examples for each subroutine such as presently found in the books for the TI programs. These model examples will show exactly what the user may expect to see in the display upon executing each step. In each case, the reader will find, in addition to the Register Contents as currently published in the textbooks, a set of assignments used by the program along with a listing of labels used (which may also be seen in the complete listing of the programs in the appendix).

The reader should remember to assign, record (and subsequently read) the magnetic cards in USER mode so as to preserve those assignments. In those assignments, we often use lower case versions of capital letters even when they do not, technically, exist. Thus, [i] is used for the alphanumeric [<] since the latter is located above [I] and is effected by pressing the gold shift key, then [I]. Similar remarks apply to [g] (really [%]), [h] (really [#]) and [j] (really [>]). Of course [a], [b], [c], etc. are actually listed in the alpha keyboard.

Since the [X<>Y] key is used in so many programs, and its execution is considerably slower in USER mode, it is advisable to assign the function X<>Y to this key at the start of a session. Such an assignment cannot be made permanent in the programs, but will remain in effect unless the master clear is used.



## PROBABILITY BY CALCULATOR

### Section 1.3: The Calculator

It is assumed here that the reader is reasonably familiar with the Owner's Handbook and Programming Guide for the HP-41C. The general remarks found in this section apply to the HP as well. It has already been remarked that a card reader will be needed to follow the program outlined here. It is possible to do without the magnetic cards for some of the programs since they may be keyed in once and the continuous memory feature of the HP will preserve them. But even that generous memory allowance will soon be used up and programs will have to be replaced to follow all of the subroutines presented in these textbooks. The magnetic cards removes the necessity of having to re-key so many separate programs. Guidelines for recording magnetic cards will be found in the Card Reader handbook and should be consulted.

### Section 1.4: The Programs

Many of the remarks in this section will not apply directly to the HP calculator and, again, the Owner's Handbook should be consulted for specifics regarding the related keys. The programs will appear in print-out (see Appendix) as numbered steps with the corresponding mnemonic code (no key code as with the TI). Most are self-explanatory and the Function Index given in the back of the Handbook will be found very helpful should the reader encounter any that are not immediately recognized. Naturally, the programs should be identical with the listings given in the Appendix before any recording takes place.

### Section 2.4: Counting Problems

The internal function FACT in the HP will replace the use of label C in Pgm 16 of the TI to display factorials as discussed on page 21. That function has exactly the same restriction, namely, that  $n$  must be any positive integer between 0 and 69 inclusive, displaying OUT OF RANGE for larger values. There are no internal programs to handle permutations and combinations directly so they have been programmed in the first card program labeled ZP2. You will find the instructions under Steps 7 and 8. Each scheme prompts you for an input of first  $N$  and then  $R$  to compute the corresponding values. (The HP alphanumerics do not permit lower case letters so the notation differs just slightly from the book.) With these routines, the answers to the problems in this section may be verified.

### Section 2.5: Conditional Probability

The rest of program ZP2 has to do with Bayes probabilities and the instructions match those for the TI exactly (with  $a, b, c$ , etc. replacing  $A', B', C'$ ) as previously remarked.

ZP2 (Assigned [e])		USER INSTRUCTIONS (HP)		SIZE $\geq$ 090
STEP	PROCEDURE	ENTER	PRESS	DISPLAY
1.	Initialization	xxx	[e]	0.0000
2.	Input probabilities (Repeat for $j = 1, 2, \dots, k$ ) NOTE: If $\Pr(C_j) \equiv 1/k$ , use Step 2'	$\Pr(E C_j)$ $\Pr(C_j)^j$	[A] [R/S]	$j$ $j$
2'.	a. Input partition size b. Input given priors	$k$ $\Pr(E C_j)$	[E] [R/S]	$1/k$ $j$
3.	Compute Bayes posterior probability $\Pr(C_i E)$	$i$	[B]	$\Pr(C_i E)$
4.	a. Initialize for sensitivity analysis b. Recall given priors c. Input new cause probabilities (Repeat for $j = 1, 2, \dots, k$ ) NOTE: If new $\Pr(C_j) \equiv 1/k$ , use Step 4'	xxx  New $\Pr(C_j)$	[e] [D] [R/S]	0.0000  $\Pr(E C_j)$ $j$
4'.	a. Initialize b. Input partition size	xxx $k$	[e] [d]	0.0000 $k$
5.	Compute $\Pr(E)$ (Law of Total Probability)	xxx	[a]	$\Pr(E)$
6.	<u>Birthday Problem</u> ( $E_k$ is the event that two or more among $k$ people in a room have the same birth date.)	$k$	[C]	$\Pr(E_k)$
7.	Calculate $P_R^N$	 $N$ $R$	[b] [R/S] [R/S]	$N = ?$ $R = ?$ $P_R^N$
8.	Calculate $C_R^N$	 $N$ $R$	[c] [R/S] [R/S]	$N = ?$ $R = ?$ $C_R^N$

### Register Contents

00	Used	10		20	$\Pr(E C_1)$
01		11	Used	21	$\Pr(C_1)$
02		12	Used	22	$\Pr(E C_2)$
03	k	13	1/k	23	$\Pr(C_2)$
04	$\Sigma\Pr(E C_j)$	14	Used	24	.
05		15		25	.
06		16		26	.
07		17		27	
08		18		28	
09		19		29	

### Assignments

ZP2 | e

### Labels Used

02    A    a  
 03    B    b  
 04    C    c  
 05    D    d  
 08    E  
 09  
 10  
 11  
 12

EXAMPLES ZP2 (1) Suppose in medical diagnostics a particular symptom (E) always occurs in conjunction with three diseases  $C_1$ ,  $C_2$ ,  $C_3$  with respective probabilities 0.90, 0.09 and 0.009 or else occurs rarely (0.001) with no apparent reason ( $C_4$ ) at all. National statistics show that most people are free of the three diseases,  $\Pr(C_4) = 0.99$ , and disease  $C_1$  is fairly rare,  $\Pr(C_1) = 0.0001$ . Diseases  $C_2$  and  $C_3$  occur with respective probabilities 0.0045 and 0.0054.

Bayes Format:

<u>Events</u>	<u>Conditional Priors</u>	<u>Cause Probabilities</u>	<u>Conditional Posteriors</u>
$C_1$ = Disease #1	0.90	0.0001	0.0587
$C_2$ = Disease #2	0.09	0.0045	0.2641
$C_3$ = Disease #3	0.009	0.0054	0.0317
$C_4$ = No Disease	0.001	0.9900	0.6455
<hr/>			
E = Symptom			$\Pr(E) = 0.0015$

Calculator Solution:

<u>ZP STEP</u>	<u>ENTER</u>	<u>PRESS</u>	<u>DISPLAY</u>	<u>COMMENTS</u>
Step 1		[e]	0.0000	Initialization
Step 2	.9	[A]	1.0000	First conditional prior
"	.0001	[R/S]	1.0000	Shows one pair entered
"	.09	[A]	2.0000	Second conditional prior
"	.0045	[R/S]	2.0000	Shows two pairs entered
"	.009	[A]	3.0000	Third conditional prior
"	.0054	[R/S]	3.0000	Shows three pairs entered
"	.001	[A]	4.0000	Fourth conditional prior
"	.99	[R/S]	4.0000	Shows four pairs entered
Step 3	1	[B]	0.0587	First conditional posterior
"	2	[B]	0.2641	Second conditional posterior
"	3	[B]	0.0317	Third conditional posterior
"	4	[B]	0.6455	Fourth conditional posterior
Step 4		[a]	0.0015	Probability of E

EXAMPLES ZP2 (2) A manufacturer of hand-held calculators has three different assembly plants F, M and T. These three plants historically produce defective items with respective probabilities 0.01, 0.02 and 0.04. Plant F produces 50% of the calculators while plants M and T produce, respectively, 30% and 20%.

Original Bayes Format:

<u>Events</u>	<u>Priors</u>	<u>Causes</u>	<u>Posteriors</u>
$C_1$ = Plant A	0.01	0.50	0.2632
$C_2$ = Plant B	0.02	0.30	0.3158
$C_3$ = Plant C	0.04	0.20	0.4211
<hr/>			
E = Defective			Pr(E) = 0.0190

Calculator Solution for Changing Priors to  $p_i \equiv 1/3$  (after original entry):

<u>ZP STEP</u>	<u>ENTER</u>	<u>PRESS</u>	<u>DISPLAY</u>	<u>COMMENTS</u>
Step 4a.		[e]	0.0000	Initialization
Step 4b.		[D]	0.0100	First prior displayed
Step 4c.	1/3	[R/S]	1.0000	First cause prob. changed
Step 4b.		[D]	0.0200	Second prior displayed
Step 4c.	1/3	[R/S]	2.0000	Second cause prob. changed
Step 4b.		[D]	0.0400	Third prior displayed
Step 4c.	1/3	[R/S]	3.0000	Third cause prob. changed
Step 3	1	[B]	0.1429	New $\Pr(E C_1)$
"	2	[B]	0.2857	New $\Pr(E C_2)$
"	3	[B]	0.5714	New $\Pr(E C_3)$

Alternate Solution:

Step 4'a.		[e]	0.0000	Initialization
Step 4'b.	3	[d]	3.0000	Partition size entered
Step 3	1	[B]	0.1429	New $\Pr(E C_1)$
"	2	[B]	0.2857	New $\Pr(E C_2)$
"	3	[B]	0.5714	New $\Pr(E C_3)$

EXAMPLES ZP2 (3) Calculate  $P(\frac{10}{2})$ ,  $4!$  and  $C(\frac{52}{5})$  .

Solution:

<u>ZP STEP</u>	<u>ENTER</u>	<u>PRESS</u>	<u>DISPLAY</u>	<u>COMMENTS</u>
Step 7.		[b]	N=?	Prompts for entry of N
	10	[R/S]	R=?	Asks for the value of R.
	2	[R/S]	90.0000	Display $P(\frac{10}{2}) = 90$ .
		[b]	N=?	Initializes permutation routine.
	4	[R/S]	R=?	Asks for the value of R.
	4	[R/S]	24.0000	Displays $4! = P(\frac{4}{4})$ .
		[c]	N=?	Initializes combination routine.
	52	[R/S]	R=?	Prompts for entry of R=5.
	5	[R/S]	2,598,960	Displays $C(\frac{52}{5})$ , the total number of poker hands.

NOTE:  $4!$  may also be computed by executing the function FACT.



### Section 3.2: Moments of a Random Variable

Just as with ZP2, the HP version of ZP3.2 (denoted ZP3-2 since a period may not be used in an ALPHA label) is almost exactly the same as the TI version. In the discussion of the program on page 57, you may ignore the warnings concerning capacity limitations and repartitioning the calculator. Sizing the HP to allow for more memory registers will accomplish the same thing. In any case, such problems will never arise in the applications presented here. You might observe the use of the alternate HP form,  $[X<>Y]$ , for the X exchange Y key throughout this report. This is merely a concession to ease of printing. (HP Y-register is always used in place of TI T-register)

The one place where there is serious departure from the TI-59 is in repeated application of LABS. To erase a previous application with the TI, one need only over-write the old algorithm with the new one, paying no attention to what may or may not remain when the new algorithm is finished with a RETURN instruction. But, because algorithms must be created as individual sub-routines with the HP, erasing is not so simple. At Step 4f. the beginning of the old algorithm is displayed at program step 88. The steps from this point on need to be erased and this may be accomplished with the internal function DEL. Then the new algorithm may be inserted where the old one resided and the program will function for the new case. As suggested in the footnote to the user instructions that follow, you might assign DEL to a label like [g] if a lot of erasing is to be done. Unfortunately, the DEL function cannot be recorded as an instruction in program memory so this will only be helpful for given session.

On page 59, an HP version of the algorithm for  $g(x)=3x+19$  would be

RCL 09,3,\*,19,+,RTN

and  $g(x)=(x*x-4)/(6x+7)$  could be keyed in as

4,RCL 09, ENTER,\*,-,CHS,RCL 09,6,\*,7,+,/,RTN

Here we have taken the liberty of using the printed symbol / for the division operator and the symbol \* for multiplication.

### Section 3.3: Hypergeometric and Binomial Distributions

#### Section 3.4: Other Discrete Distributions

For both of these sections, the HP programs are practically identical with the TI programs. The basic difference is that the HP initialization step is to press [e] instead of RST. Having so used label e, label J is used for the number of trials, Y, to  $r^{\text{th}}$  success at NB5 in program ZP3-4.



ZP3-2 (Assigned [e])		USER INSTRUCTIONS (HP)		SIZE 060
STEP	PROCEDURE	ENTER	PRESS	DISPLAY
1.	Distribution Entry a. Initialize b. Enter (in order ) $x_i, p_i$ (Repeat for $i = 1, 2, \dots, N \leq 20$ ; $x_1 < x_2 < \dots < x_N$ )	$x_i$ $p_i$	[e] [A] [R/S]	0.0000 $x_i$ i.0000
2.	Calculate $P(x)$ (x-code = j where $x_j \leq x < x_{j+1}$ )	x-code	[C]	$P(x)$
3.	Calculate $E(X), V(X)$ (after Step 1)		[E] [X<>Y]	$E(X)$ $V(X)$
4.	Calculate $E[g(X)], V[g(X)]$ (after Step 1) a. Initialize NOTE: It is understood that [ALPHA] must be used for label B. b. Enter Program Mode c. Key in $g(x)$ where $x \in R_{09}$ (Avoid labels already in use, end with RTN) d. Exit Program Mode e. Calculate Moments. f. To ERASE Algorithm in [B], complete Steps a,b; then  let nnn be at least as large as the number of Steps in [B] <sup>†</sup>		[GTO] [B]  [PRGM] - - - [PRGM] [D] [X<>Y]  [SST] [g] nnn [PRGM]	x.xxxxx  87 LBL B    x.xxxxx $E[g(X)]$ $V[g(X)]$  88 yy DEL --- 87 LBL B x.xxxxx

<sup>†</sup> For repeated uses of this step use ASN to assign DEL to g(%).

Register Contents

00	Used	10	P(x)	20	$x_1$
01	x-address	11		21	$p_1$
02	p-address	12		22	$x_2$
03	N	13		23	$p_2$
04	$x_i p_i$	14		24	$x_3$
05	$x_i^2 p_i$	15		25	$p_3$
06	Mean	16		26	.
07	2nd Moment	17		27	.
08	Variance	18		28	.
09	x-value	19		29	

Assignments

ZP3-2 | e

Labels Used

01 A

02 B

03 C

04 D

05 E

06

07

EXAMPLE ZP3-2.  $X = \#$  daily sales of a morning newspaper at a local drugstore.

x:	0	1	2	3	4	5
p(x):	0.01	0.01	0.04	0.03	0.67	0.24

Solution:

<u>ZP STEP</u>	<u>ENTER</u>	<u>PRESS</u>	<u>DISPLAY</u>	<u>COMMENTS</u>
Step 1a.		[e]	0.0000	Initialization
Step 1b.	0	[A]	0.0000	Enter first x-value
"	.01	[R/S]	1.0000	Enter first p-value
"	1	[A]	1.0000	Enter second x-value
"	.01	[R/S]	2.0000	Enter second p-value
"	2	[A]	2.0000	Enter third x-value
"	.04	[R/S]	3.0000	Enter third p-value
"	3	[A]	3.0000	Enter fourth x-value
"	.03	[R/S]	4.0000	Enter fifth p-value
"	4	[A]	4.0000	Enter fifth x-value
"	.67	[R/S]	5.0000	Enter fifth p-value
"	5	[A]	5.0000	Enter sixth x-value
"	.24	[R/S]	6.0000	Enter sixth p-value

Calculate  $P(4.5)$  ( $x\text{-code} = 5$  since  $x_5 \leq 4.5 < x_6 = 5$ )

Step 2	5	[C]	0.7600	Note that $x_1=0$ so that $x_5=4$ .
--------	---	-----	--------	-------------------------------------

Calculate  $\mu = E(X)$  and  $\sigma^2 = V(X)$ .

Step 3		[E]	4.0600	Display $\mu = 4.06$
		[X<>Y]	0.6764	Display $\sigma^2 = 0.6764$

Calculate  $E[g(X)]$  and  $V[g(X)]$  where  $g(x) = 25x - 50$  is net daily income.

Step 4a.	[GTO]	GTO __	Initialize
	[ALPHA]	GTO __	
	[B]	GTO B _	
	[ALPHA]	x.xxxxx	
Step 4b.	[PGRM]	87 LBL B	
Step 4c.	[RCL]	88 RCL __	
	09	88 RCL 09	Brings current x-value into
	25	89 25 _	$R_X$

<u>ZP STEP</u>	<u>ENTER</u>	<u>PRESS</u>	<u>DISPLAY</u>	<u>COMMENTS</u>
		[x]	90 *	Multiplies x by 25,
		50	91 50 _	and subtracts
		[-]	92 -	50.
		[RTN]	93 RTN	Ends algorithm.
Step 4d.		[PRGM]	x.xxxx	Exit Program mode.
Step 4e.		[D]	51.5000	Calculates "average" daily net income as 51.5 cents.
		[X<>Y]	422.7500	Exhibits variance in cents <sup>2</sup> .
		[USER]√x	20.5609	Shows $\sigma$ as 20.56 cents.
<hr/>				
Calculate $E[g(X)]$ and $V[g(X)]$ where $g(x)$ is daily profit.				
Step 4f.		[GTO]	GTO __	Initialize
		[ALPHA]	GTO _	
		[B]	GTO B _	
		[ALPHA]	x.xxxx	
		[PGRM]	87 LBL B	Enters ZP-3.2 program at B.
		[SST]	88 yy	Locates first step of last algorithm
		[g]	DEL ___	Prepares to delete algorithm steps.
		010	87 LBL B	Deletes to END statement.
Step 4b.		2	88 2 _	Enters 2 for comparison with x.
		[RCL]09	89 RCL 09	Retrieves x.
		[X>Y?]	90 x>y?	Asks if x>y?
		[GTO]20	91 GTO 20	Proceeds to subroutine to be constructed for evaluating $g(x)$ .
		0	92 0 _	Otherwise $g(x)=0$
		[RTN]	93 RTN	Ends that part of algorithm
		[LBL]20	94 LBL 20	Prepares to define subroutine.
		25	95 25	$g(x) = 25x - 50$ .
		[x]	96 *	A return is not necessary
		50	97 50	since it is controlled by END.
		[-]	98 -	
		[PRGM]	x.xxxx	Exits program mode.
Step 4c.		[D]	52.2500	Calculates and exhibits "average" daily profit of 57.25 cents.
Step 4d.		[X<>Y]	313.6875	Shows profit variance.

ZP3-3 (Assigned [e])		USER INSTRUCTIONS (HP)		SIZE 030
STEP	PROCEDURE	ENTER	PRESS	DISPLAY
	<u>Hypergeometric Distribution</u>			
H1	Initialization		[e]	0.0000
H2	Enter Parameters	N	[STO]14	N
	( $n \leq N$ and $0 < M \leq N$ )	M	[STO]15	M
		n	[STO]13	n
H3	Calculate $P(k) = \Pr(X \leq k)$	k	[A]	P(k)
	$p(k) = \Pr(X = k)$		[X<>Y]	p(k)
H4	Calculate $Q(k) = \Pr(X > k)$	k	[a]	Q(k)
	$p(k) = \Pr(X = k)$		[X<>Y]	p(k)
	NOTE: Repeat H <sub>3</sub> and/or H <sub>4</sub> as often as desired.			
	<u>Binomial Distribution</u>			
B1	Initialization		[e]	0.0000
B2	Enter Parameters ( $M \leq N$ )	N	[STO]14	N
		M	[STO]15	M
		n	[STO]13	n
B3	Calculate $P(k) = \Pr(X \leq k)$	k	[B]	P(k)
	$p(k) = \Pr(X = k)$		[X<>Y]	p(k)
B4	Calculate $Q(k) = \Pr(X > k)$	k	[b]	Q(k)
	$p(k) = \Pr(X = k)$		[X<>Y]	p(k)
	NOTE: Repeat B <sub>3</sub> and/or B <sub>4</sub> as often as desired.			
E	Display E(X) and V(X) (following any application of H <sub>3</sub> (H <sub>4</sub> ) or B <sub>3</sub> (B <sub>4</sub> ))		[E] [X<>Y]	E(X) V(X)

### Register Contents

00		10	$P(x)$	20	Used
01	$N$	11	$\mu$	21	$1 - M/N$
02	$r_k$	12	$\sigma^2$	22	$M/N$
03		13	$n$	23	Used
04		14	$N$	24	$N-M$
05		15	$M$	25	
06	Used; $p(k)$	16	$p(0)$	26	
07	Used; $p(k)$	17		27	
08	Used	18		28	
09		19		29	

### Assignments

ZP3-3	e
PMTON	i
CMBON	h

### Labels Used

01	A	a
02	B	b
03	E	
04		
05		
06		
07		
08		
11		
12		
13		
19		

Note: PMTON and CMBON require storage of  $n$  in  $R_{01}$  and  $k$  in  $R_{02}$ , for execution using XEO ' '

EXAMPLES ZP3-3. An urn contains five black balls and seven white balls.

- (1) A sample of size 3 is drawn without replacement. Calculate the probability of obtaining exactly two black balls, at most two black balls and at least two black balls. Answers are, respectively,  $p(2)=0.32$ ,  $P(2)=0.95$  and  $Q(1)=0.36$ .  
(See display below.)
- (2) Repeat (a) for a sample drawn with replacement. Answers are, respectively,  $p(2)=0.30$ ,  $P(2)=0.93$ ,  $Q(1)=0.38$ .
- (3) For each of (a) and (b) determine the mean and variance of  $X$ , the number of black balls in the sample.

Ans. (a)  $\mu = 1.25$ ,  $\sigma^2 = 0.60$ ; (b)  $\mu = 1.25$ ,  $\sigma^2 = 0.73$ .

Solution (1), (3):

<u>ZP STEP</u>	<u>ENTER</u>	<u>PRESS</u>	<u>DISPLAY</u>	<u>COMMENTS</u>
H1		[e]	0.0000	Only necessary when starting a new problem.
H2	12	[STO]14	12.0000	
	5	[STO]15	5.0000	
	3	[STO]13	3.0000	
H3	2	[A]	0.9545	Displays CDF $P(2)$ first
		[X<>Y]	0.3182	Displays $p(2)$ .
H4	1	[a]	0.3636	Displays $Q(1)$ . No re-initialization necessary.
E		[E]	1.2500	Displays mean and variance
		[X<>Y]	0.5966	

Solution (2), (3):

B1		[e]	0.0000	Signals the start of a new program even though the same parameters are involved (B2 unnecessary)
B3	2	[B]	0.9277	Binomial CDF differs from $H_3$
		[X<>Y]	0.3038	Binomial $p(2)$ .
B4	1	[b]	0.3762	$Q(1) = \Pr(X > 1) = \Pr(X \geq 2)$
E		[E]	1.2500	Mean
		[X<>Y]	0.7292	Variance



ZP3-4 (Assigned [e])		USER INSTRUCTIONS (HP)		SIZE 030
STEP	PROCEDURE	ENTER	PRESS	DISPLAY
	<u>Binomial Distribution</u>			
bin 1	Initialization		[e]	0.0000
bin 2	Enter Parameters	n	[STO]13	n
		p	[STO]22	p
bin 3	Calculate $P(k) = \Pr(X \leq k)$	k	[B]	P(k)
			[X<>Y]	p(k)
bin 4	Calculate $Q(k) = \Pr(X > k)$	k	[b]	Q(k)
			[X<>Y]	p(k)
	NOTE: Repeat 3 and 4 as often as desired			
	<u>Poisson Distribution</u>			
PO1	Initialization for Poisson		[e]	0.0000
PO2	Enter Parameters	t	[STO]13	t
		$\lambda$	[STO]22	$\lambda$
PO3	Calculate $P(k) = \Pr(X \leq k)$	$k \geq 0$	[C]	P(k)
			[X<>Y]	p(k)
PO4	Calculate $Q(k) = \Pr(X > k)$	$k \geq 0$	[c]	Q(k)
			[X<>Y]	p(k)
	NOTE: See Note in bin			
	<u>Negative Binomial Distribution</u>			
NB1	Initialization for Negative Binomial		[e]	0.0000
NB2	Enter Parameters	r	[STO]13	r
		p	[STO]22	p
NB3	Calculate $P(k) = \Pr(X \leq k)$ $p(k) = \Pr(X = k)$	$k \geq 0$	[A]	P(k)
			[X<>Y]	p(k)
NB4	Calculate $Q(k) = \Pr(X > k)$ $p(k) = \Pr(X = k)$	$k \geq 0$	[a]	Q(k)
			[X<>Y]	p(k)
NB5	Calculate $P(k) = \Pr(Y \leq k)$ $p(k) = \Pr(Y = k)$	$k \geq r$	[J]	P(k)
			[X<>Y]	p(k)
	NOTE: See Note in bin; Y = X+r = # Trials			

STEP	PROCEDURE	ENTER	PRESS	DISPLAY
	<u>Geometric Distribution</u>			
G1	Initialization for Geometric		[e]	0.0000
G2	Enter Parameter	p	[STO]22	p
G3	Calculate $P(k) = \Pr(Y \leq k)$	$k \geq 1$	[D]	$P(k)$
	$p(k) = \Pr(Y = k)$		[X<>Y]	$p(k)$
G4	Calculate $Q(k) = \Pr(Y > k)$	$k \geq 1$	[d]	$Q(k)$
			[X<>Y]	$p(k)$
	NOTE: See note under bin.			
E	Display $E(X)$ and $V(X)$ (after any of the foregoing routines)		[E] [X<>Y]	$E(X)$ $V(X)$

Register Contents:

00	Used	10	z	20	Used
01		11	$\mu$	21	q
02		12	$\sigma^2$	22	$p(\lambda)$
03		13	$n(t, r)$	23	
04		14		24	
05		15		25	
06	Used ( $p(k)$ )	16	$p(0)$	26	
07	Used ( $p(k)$ )	17		27	
08		18		28	
09		19		29	

Assignments

ZP3-4 | e

Labels Used

05 A a  
07 B b  
08 C c  
11 D d  
13 E  
14 J  
15  
18  
19  
20  
29

EXAMPLES ZP3-4

- (1) (Binomial model) The probability of hitting a target in a single trial is 0.3. Suppose 10 independent firings are made. Calculate the probability of 3 hits, no more than 4 hits, at least 6 hits and the mean and variance of the number of hits.

Solution (1), (3):

<u>ZP STEP</u>	<u>ENTER</u>	<u>PRESS</u>	<u>DISPLAY</u>	<u>COMMENTS</u>
bin 1		[e]	0.0000	Initialize program.
bin 2	10	[STO]13	10.0000	Enter parameters.
"	.3	[STO]22	0.3000	
bin 3	3	[B]	0.6496	Display the CDF at 3.
		[X<>Y]	0.2668	Required probability $p(3)$ .
bin 3	4	[B]	0.8497	Repeating to find $P(4)$ .
bin 4	5	[b]	0.0473	Required $Q(5) = \Pr(X \geq 6)$
E		[E]	3.000	Mean value $np = 3$ .
		[X<>Y]	2.1000	Variance of $X = npq$ .

- (2) Poisson model) Telephone calls arrive at a switchboard at the rate of 10 per hour. What is the probability of at most 3 calls in the next 20 minutes? Exactly 3? The mean number of calls?

Solution:

P01		[e]	0.0000	Initialize program.
P02	0.3333	[STO]13	0.3333	Enter total time period 20 min.
"	10	[STO]22	10.0000	Enter rate $\lambda = 10$ per hour.
P03	3	[C]	0.5730	$P(3) = \Pr(X \leq 3)$ .
		[X<>Y]	0.2202	$p(3) = \Pr(X = 3)$ .
E		[E]	3.3333	Mean number of calls in 20 mins.

- (3) (Negative Binomial model) A fly fisherman estimates that his probability of catching a fish on a given cast of his rod is 0.05. He decides to keep trying until he catches three fish. What is the probability that he will need to cast at least 10 times and what is the expected number of failures? What is the probability of 9 trials? The mean number of trials?

Solution:

<u>ZP STEP</u>	<u>ENTER</u>	<u>PRESS</u>	<u>DISPLAY</u>	<u>COMMENTS</u>
NB1		[e]	0.0000	Initialize program.
NB2	3	[STO]13	3.0000	Enter r parameter of 3.
"	.05	[STO]22	0.0500	Enter probability of obtaining 1.
NB4	6	[a]	0.9916	Probability that the number of failures is at least 7, Q(6).
		[X<>Y]	0.0026	Probability of exactly 6 failures.
E		[E]	57.0000	Mean number of failures.
NB5	9	[J]	0.0084	Probability of no more than 9 trials.
		[X<>Y]	0.0026	Probability of exactly 9 trials.

- (4) Geometric model) An item has failure probability 0.005 and is cycled until it fails. What is the expected number and standard deviation of the number of cycles? What is the probability that number exceeds 10?

Solution:

G1		[e]	0.0000	Initialize program.
G2	.0005	[STO]22	0.0005	Enter single parameter.
G3	10	[d]	0.9950	Displays CCDF at 10, Pr(Y > 10).
E		[E]	2000.0000	Mean cycles to failure.
		[X<>Y]	3,998,000	Variance.
		[USER] $\sqrt{x}$	1999.4999	Standard deviation.
		[e]	0.0000	Clears program.

### Section 4.3: Normal Distribution

The user instructions for the HP version of ZP4 are practically identical to those for TI given in the book. Label [J] is used for initialization in place of RST; otherwise, pressing the same labels produces the same results. Using the parameter choices 0 and 1 at step N1 in ZP4 replaces ML-14 in the TI master module everywhere the discussion refers to the latter starting on page 109.

### Section 4.4: Uniform Family; Sampling

As previously indicated, the serious departure from the TI format occurs in the random number generator and consequently, both the instructions and the results will differ from those published in the book. The departure begins on page 121. The random number generator adopted for the HP programs is one developed by Don Malm for the HP-65 User's Library and is referred to on page 24 of the HP-41C Standard Applications manual. The algorithm used is the simple one.

$$r_{n+1} = \text{FRC} (9821 * r_n + .211327)$$

It allegedly will generate one million random numbers when a seed between 0 (inclusive) and 1 is used. This random number generator is initialized by pressing [I] whereupon you are prompted for a seed which is then entered with [R/S] instead of TI [E']. For some degree of uniformity with the TI illustrations, you may use a decimal point in front of each of the seeds given in the book, such as .419 in Example 4.10 on page 121. Subroutine RNDMU, assigned to label [i], replaces [SBR] [D.MS] and outputs a random number from the unit interval. For this illustration, the output of the HP program is .2104 instead of 0.65816 as listed, and the corresponding value of  $x$  will accordingly be 15,589.

In example 4.11, ML-15 is used to generate normal deviates. Here, Step N6, programmed as label [G] of the Normal Distribution program in ZP4, may be used in its place. For the example, using a seed of .793, the output should be 56.2958. (Of course, the parameters must be suitably stored by Step N1 to begin with.)

Continuing on page 122, the subroutine [P→R] replaces the TI key [ $\bar{x}$ ], while [R→P] replaces [INV] [ $\bar{x}$ ]. In Example 4.12, the sample values will be 47,30,56,48 with a mean of 47.3 and a standard deviation of 10.4. The next successive values are 49,45,57,50,61 with a mean of 49.8 and a standard deviation of 8.5. In Example 4.15, the ten successive values will be 727,708,417,3401,326,213,1770,686,825,2783 with running counts checked in Register 06 rather than 03. The mean will be 1147.9 rather than the published 1311. In Example 4.16, using a seed of .66, the successive values will be 0,2,4,6,2.

If you have been able to check these examples, then, while your answers will differ from the published ones whenever random number generation is called in the problems that follow, you may rely on the results nevertheless.

ZP4 (Assigned [J])		USER INSTRUCTIONS (HP)		SIZE 030 Σ REG 01	
STEP	PROCEDURE	ENTER	PRESS	DISPLAY	
	<u>Exponential Distribution</u>				
E1	Initialization		[J]	0.0000	
E2	Enter Parameter	$\lambda$	[STO]22	$\lambda$	
E3	Compute $P(x)$ and $Q(x)$ NOTE: $\lambda x$ must not exceed 228	$x \geq 0$	[E] [X<>Y]	$P(x)$ $Q(x)$	
E4	Calculate 100(1- $\alpha$ )th Percentile NOTE: Repeat E <sub>3</sub> and E <sub>4</sub> at will	$\alpha$	[e]	$x_\alpha$	
E5	Generate sample of size $n$ a. Initialize Random Number Generator b. Enter Seed ( $0 \leq \text{Seed} < 1$ ) c. Execute Step E2 d. Generate $x$ (Repeat $n$ times)	Seed	[I] [R/S]  [B]	SEED? Seed $\lambda$ $x$	
	<u>Normal Distribution</u>				
N1	Enter Parameters	$\mu$ $\sigma^2$	[STO]11 [STO]12	$\mu$ $\sigma^2$	
N2	Compute $P(x)$ and $Q(x)$	$x$	[C] [X<>Y]	$P(x)$ $Q(x)$	
N3	Compute $\text{Pr}(x_1 < X < x_2)$ a. Enter $x_1$ b. Enter $x_2$ and compute.	$x_1$ $x_2$	[D] [R/S] [X<>Y]	$P(x_1)$ $\text{Pr}(x_1 < X < x_2)$ $\text{Pr}(X < x_1)$ $+ \text{Pr}(X > x_2)$	
N4	Calculate Standard 100(1- $\alpha$ )th Percentile	$\alpha$	[c]	$z_\alpha$	
NB5	Calculate General 100(1- $\alpha$ )th NOTE: Repeat N <sub>2</sub> -N <sub>5</sub> as often as desired	$\alpha$	[d]	$x_\alpha$	
N6	Generate sample of size $n$ a. Initialize Random Number Generator b. Enter Seed ( $0 \leq \text{Seed} < 1$ ) c. Execute Step N1 d. Generate $x$ (Repeat $n$ times)	Seed	[I] [R/S]  [G]	SEED? Seed  $x$	



ZP4 USER INSTRUCTIONS (HP)				
STEP	PROCEDURE	ENTER	PRESS	DISPLAY
	<u>Uniform Distribution</u>			
U1	Initialization		[J]	0.0000
U2	Enter Parameters	a	[STO]13	
		b	[STO]14	
U3	Compute $P(x)$ and $Q(x)$	x	[A]	$P(x)$
			[X<>Y]	$Q(x)$
U4	Compute 100(100(1- $\alpha$ )th Percentile	$\alpha$	[SF]05	xxx
			[A]	$x_\alpha$
U5	Generate sample of size n from $R_X = \{e_1, e_2, \dots, e_N\}$ corresponding to LABELS 00, 01, ..., K.			
	a. Initialize Random Number Generator		[I]	SEED?
	b. Enter Seed ( $0 \leq \text{Seed} < 1$ )	Seed	[R/S]	Seed
	c. Execute Step U2 with $a = 0$ , $b = K$			
	d. Generate Random Label R		[a]	R
	e. Enter e-value corresponding to R. Repeat d and e for $i = 1, 2, \dots, n$ .	$x_i$	[R/S]	i
	NOTE 1. Summary stats stored in $R_{01} - R_{06}$ .			
	NOTE 2. To generate from $\{A, A+1, \dots, B\}$ execute steps a-d with $a = A$ , $b = B$			
M	For each of the above distribu- tions $\mu$ and $\sigma^2$ may be recovered after computing any $P(x)$ .		[b] [X<>Y]	$\mu$ $\sigma^2$



Register Contents:

00	Used	10	$z = (x - \mu) / \alpha$	20
01	Used	11	$\mu$	21
02	by $\Sigma$ REG	12	$\sigma^2$	22 $\lambda$
03		13	$z_\alpha(z)$	23
04		14	$b(K)$	24
05		15	$b-a$	25 Used
06	$p(x)$	16		26 Used
07	$P(x)$	17		27
08	$P(x_1) - P(x_2)$	18		28
09	Seed	19		29

Assignments

ZP4	J
ZCDF	H
GEN-INI	I
RNDMU	i
XBAR	P→R
SD	R→P

Labels Used

03	A	a
07	B	b
09	C	c
11	D	d
12	E	e
15	G	
16		
17		

# EXAMPLES ZP4

- (1) Time to failure,  $X$ , is exponential with failure rate  $= 0.0001$ .
- Determine the reliability at  $x_0 = 100$  and at  $x_0 = 500$ .
  - What would the failure rate have to be to achieve a reliability of 0.99 at 500 hours?
  - Calculate mean and median time to failure and the variance of  $X$ .

Solution (1), (3):

<u>ZP STEP</u>	<u>ENTER</u>	<u>PRESS</u>	<u>DISPLAY</u>	<u>COMMENTS</u>
E1		[J]	0.0000	Initialize exponential subroutine.
E2	.0001	[STO]22	0.0001	Single parameter stored in $R_{22}$ .
E3	100	[E]	0.0100	Displays $P(100)$
"		[X<>Y]	0.9900	Displays $Q(100)$ , the reliability at 100.
E3	500	[E]	0.0488	$P(500)$ displayed.
"		[X<>Y]	0.9512	$Q(500) =$ reliability at 500
E2	500	[STO]22	500.0000	Treating 500 as $\lambda$ temporarily for computation in b.
E5	.99	[e]	2.0101-05	Value of $\lambda = \ln(0.99)/500$
E2	.0001	[STO]22	0.0001	Restores true $\lambda$ in $R_{22}$ for the model.
M		[b]	10,000.0000	Displays mean time to failure
		[X<>Y]	100,000,000	Displays $\sigma^2 = \mu^2$ for this model
E4	0.5	[e]	6931.0000	The median time to failure
E3		[E]	0.5000	Verifies that $P(6931) = 0.50$ .

- (2) A standardized test is administered to incoming freshmen at a university. Scores,  $X$ , are assumed to be normally distributed and, based on thousands of past scores, it is assumed that  $\mu = 100$  and  $\sigma^2 = 245$ . For an incoming freshman chosen at random what is the probability that the test score will be:
- greater than 110?
  - less than 90?
  - between 75 and 125?
- If only the top 80% of incoming freshmen are to be admitted on the basis of this test, what would the minimum passing score be?

Solutions:

<u>ZP STEP</u>	<u>ENTER</u>	<u>PRESS</u>	<u>DISPLAY</u>	<u>COMMENTS</u>
-		[J]	0.0000	Clears exponential problem.
N1	100	[STO]11	100.0000	Enter the mean value.
"	245	[STO]12	245.0000	Enter the second parameter $\sigma^2$ .
N2	110	[C]	0.7385	Displays $P(110) = \Pr(X < 110)$ .
		[X<>Y]	0.2615	Displays $Q(110)$ , the required probability
		[RCL]10	0.6389	Shows the standardized value for $x = 110$ , namely, $z = (110-100)/\sqrt{245}$
N2	90	[C]	0.2615	Displays $P(90)$
N3a	75	[D]	0.9449	Displays $Q(75)$ , of minor interest
N3b	125	[R/S]	0.8898	Calculates and displays $\Pr(75 < X < 125)$
		[X<>Y]	0.1102	Displays $\Pr(X < 75) + \Pr(X > 125)$ .
N5	.80	[d]	86.8291	Displays the 20th percentile for X so that $\Pr(X > 87) = 0.80$ .

- (3) The time a passenger must wait for a commuter flight on arrival at an airport is a uniform random variable over an interval from 0 to 30 minutes.
- What is the probability that the passenger will have to wait at least 10 minutes for a flight?
  - What waiting time corresponds to a 90% chance of catching a flight?
  - What is the probability that the passenger will wait between 10 and 20 minutes?
  - What is the mean waiting time?  $\sigma^2$  and  $\sigma$ ?

Solutions:

U1		[J]	0.0000	Initialize program (clears all previous work).
U2	0	[STO]13	0.0000	Enters first parameter $a = 0$ in $R_{13}$
"	30	[STO]14	30.0000	Enters second parameter $b = 30$ in $R_{14}$
U3	10	[A]	0.3333	Displays $P(0)$ .
		[X<>Y]	0.6667	Displays the required $Q(10)$ .
U4	.90	[SF]05	0.9000	Signals calculator that percentile is coming.
U4		[A]	3.0000	Displays $x_{.90}$
		[A]	0.1000	Verifies that $P(3) = .10$ so that $Q(3) = .9$

<u>ZP STEP</u>	<u>ENTER</u>	<u>PRESS</u>	<u>DISPLAY</u>	<u>COMMENTS</u>
U4	10	[ENTER]	10.0000	Enters difference between 10 and 20 min.
"	30	[÷]	0.3333	Calculates and displays $\Pr(10 < X < 20) = (20-10)/30$ .
M		[b]	15.0000	Recalls and displays $\mu = 15$ from $R_{11}$
"		[X<>Y]	75.0000	Displays the variance $\sigma^2 = 30^2/12$
		[USER][√x]	8.6603	Displays the value of $\sigma$ .
		[J]	0.0000	Clears the program.

## Chapter 5. BIVARIATE DISTRIBUTIONS

The user instructions are practically identical to those given for the TI-59 so little has to be modified in this chapter. At Step 2 in the HP version a display of moments routine has been added which is effected by pressing [d] followed by successive presses of [R/S]. Of course, these characteristics may also be recalled manually from the respective registers just as instructed in the book.

As with ZP3-2, some modification of the routine for LABS is called for here also. The HP instructions on the matter at Step 3 are reasonably clear. As a footnote, it is advised once more that if you will be involved in a lot of erasing of old algorithms, perhaps it would be advisable to assign the delete function DEL to an unused label, like [g] for a given session. When applying LABS to various algorithms such as those found on page 142, naturally they will have to be programmed in RPN here. It is assumed that the reader is already sufficiently familiar with the HP calculator that the translation for various examples can be made without additional instruction here. Consult the OWNERS HANDBOOK AND PROGRAMMING GUIDE for any required assistance. As one example, the function  $g(x,y)=(x-1)(y-2)$  may be programmed at Step 3c as

```
RCL, 09, 1, -, RCL, 10, 2, -, *, RTN
```

Other cases can be handled in a similar fashion.

ZP5 (Assigned [e])		USER INSTRUCTIONS (HP)		SIZE 090
STEP	PROCEDURE	ENTER	PRESS	DISPLAY
1.	Distribution Entry a. Initialize b. Enter in order $x_i, y_i, p(x_i, y_i)$ (Repeat for each $i$ through $N \leq 19$ ) NOTE: $p(x_i, y_i)$ should be positive.	$x_i$ $y_i$ $p(x_i, y_i)$	[e] [A] [B] [C]	0.0000 i i i
2.	a. Compile Distribution Characteristics b. Display Characteristics  NOTE: To re-compile, enter N in $R_{03}$ after [e]		[E] [d] [R/S] [R/S] [R/S] [R/S] [R/S]	$\rho$ $\mu_x$ $\sigma_x^2$ $\mu_y$ $\sigma_y^2$ $\sigma_{xy}$ $\rho$
3.	Calculate $E[g(X,Y)], V[g(X,Y)]$ (after Step 1) a. Initialize NOTE: It is understood that [ALPHA] must be used for label a b. Enter Program Mode c. Key in $g(x,y)$ with $x \in R_{09}, y \in R_{10}$ (Avoid labels already in use; end with RTN) d. Exit Program Mode e. Calculate Moments  f. To ERASE Algorithm in [a], complete Steps a, b; then ... (Let nnn be at least as large as the number of steps in [a].) <sup>†</sup>		[GTO] [a]  [PRGM] - - -  [PRGM] [D] [X<>Y] [SST] [g]  nnn [PRGM]	x.xxxx  147 LBL a    x.xxxx E[g(X,Y)] V[g(X,Y)] 148 yy DEL --- 147 LBL a x.xxxx

For repeated applications, use ASN to assign DEL to g (%).

### Register Contents

00	Counter	10	last y	20	$x_1$
01	$x_p(x,y)$	11	$\mu_X$	21	$y_1$
02	$y_p(x,y)$	12	$\sigma_X^2$	22	$p(x_1, y_1)$
03	N	13	$\mu_Y$	23	$x_2$
04	$x^2_p(x,y)$	14	$\sigma_Y^2$	24	$y_2$
05	$y^2_p(x,y)$	15	$\sigma_{XY}$	25	$p(x_2, y_2)$
06	$xyp(x,y)$	16	$\rho$	26	.
07	$\Sigma p_{ij} = 1(g(x,y)p(x,y))$	17	$E[g(X,Y)]$	27	.
08	lastp( $g^2(x,y)p(x,y)$ )	18	$V[g(X,Y)]$	28	.
09	last x	19	Used	29	

### Assignments

ZP5 | e

### Labels Used

01 A a  
02 B d  
03 C  
D  
E



EXAMPLES ZP5 (1) Calculate the moments  $\mu_X$ ,  $\sigma_X^2$ ,  $\mu_Y$ ,  $\sigma_Y^2$ ,  $\sigma_{XY}$  and  $\rho$  for the joint distribution of Figure 5-2 duplicated below.

3	0	.2	0	0
2	0	0	.2	0
1	.1	.2	0	.3
y/x	1	2	3	4

Solutions:

<u>ZP STEP</u>	<u>ENTER</u>	<u>PRESS</u>	<u>DISPLAY</u>	<u>COMMENTS</u>
Step 1a		[e]	0.0000	Initialize ZP-5.
Step 1b	1	[A]	1.0000	First x-value for pair (1,1) entered.
"	1	[B]	1.0000	Corresponding y-value is entered.
"	.1	[C]	1.0000	Enter p(1,1) = .1; count of 1 triplet displayed.
"	2	[A]	2.0000	Enter x-value of second pair selected, (2,1).
"	1	[B]	2.0000	Enter corresponding y-value.
"	.2	[C]	2.0000	Enter p(2,1); display shows 2 triplets entered.
"	4	[A]	3.0000	Pass up cell (3,1) since p(3,1) = 0; enter next x = 4.
"	1	[B]	3.0000	Complete (4,1) entry.
"	.3	[C]	3.000	Enter p(4,1); record of 3 triplets shown.
"	3	[A]	4.0000	Only positive entry in second row, x=3.
"	2	[B]	4.0000	Enter y-value for pair (3,2).
"	.2	[C]	4.0000	Enter p(3,2).
"	2	[A]	5.0000	Enter x = 2 for only positive entry in third row
"	3	[B]	5.0000	Enter y = 3
"	.2	[C]	5.0000	Complete entry with p(2,3) = 0.2
"		[RCL] 07	1.0000	Check on data entry to see $\Sigma p(x,y) = 1$
Step 2a		[E]	-0.2736	Displays the value of $\rho$ after complete compilation and storage of moments.
Step 2b		[d]	2.7000	Displays $\mu_X$
"		[R/S]	1.0100	Displays $\sigma_X^2$
"		[R/S]	1.6000	Displays $\mu_Y$

<u>ZP STEP</u>	<u>ENTER</u>	<u>PRESS</u>	<u>DISPLAY</u>	<u>COMMENTS</u>
"		[R/S]	0.6400	Displays $\sigma_Y^2$ .
		[R/S]	-0.2200	Displays $\sigma_{XY}$ .
		[R/S]	-0.2736	Verifies again that $\rho = -0.27$ .

(2) Calculate the mean and the variance for  $g(X,Y) = XY$ .

Verify that,  $\sigma_{XY} = -0.22$

Solution:

Step 3a	[GTO]	GTO __	Preparing for entry to subroutine
	[ALPHA]	GTO _	in order to program $g(x,y)$ with
	[a]	GTO a_	$x \in R_{09}, y \in R_{10}$
	[ALPHA]	x.xxxx	
Step 3b	[PRGM]	147 LBL a	Enters program mode
"	[RCL]	148 RCL __	
		09	148 RCL 09
"	[RCL]	149 RCL __	
"		10	149 RCL 10
"	[x]	150 *	Completes formula $z = xy$
"	[RTN]	151 RTN	Required return statement for subroutine.
Step 3d	[PRGM]	x.xxxx	Return to keyboard operation (ignores display).
Step 3e	[D]	4.1000	Calculates and displays $E(XY)$ .
"	[x<>y]	3.2900	Retrieves $\sigma^2$ from $R_{07}$ to $R_X$ .
"	[x<>y]	4.1000	Returns $E(XY)$ to $R_X$ .
"	[RCL]	RCL ___	Prepares to subtract $\mu_X \mu_Y$ to
"		11	evaluate Eq. (5-4)
	[RCL]		
"		13	1.6000 Recovers $\mu_Y$ and multiplies by $\mu_X$
"	[x]	4.3200	
"	-	-0.2200	Calculation complete and $s_{XY}$ verified
Step 3f	[GTO]	GTO __	Prepare to erase algorithm in a.
	[ALPHA]	GTO _	Sends pointer to subroutine a.
	[a]	GTO a_	
	[ALPHA]	x.xxxx	
	[PRGM]	147 LBL a	Enters program mode.
	[SST]	148 yyy	Forward one step to beginning of algorithm.
	[g]	DEL ___	Execute delete function.
010		147 LBL a	Use 10 lines (more than enough)
	[PRGM]	x.xxxx	Exit program mode. Return to calculator control.
	[e]	0.0000	Erases program.

## STATISTICS BY CALCULATOR

### Section 1.3: The Calculator

This section is quite like that of ZP so that only remarks concerning the statistics module need be added here. As mentioned in the introduction, the HP module STAT PAC will be needed for some of the ZS programs. In addition, the program ZSTAT, found in the appendix, will be needed for all of the ZS programs starting in Chapter 4 since they contain the probability distributions, among other things, that are missing in STAT PAC. Most of the applications of ZSTAT occur internally within ZS programs but, occasionally, some of the subroutines are called for individually. For that reason, suggestive alphanumeric labels have been included and the program has been assigned to label [SCI] to make it convenient to access from the keyboard.

### Section 2.3: Simulation

The first departure from the TI format occurs on page 16 in the digression for computing moments of discrete distributions. A subroutine called MU-SIG and assigned to label [j] has been inserted into program ZS-2 to replace the TI use of ST-03. As the reader can see from the User Instructions that follow, the pairs are entered in opposite (but more natural) order with  $x$  first, followed by  $p$ . Instead of a running count of the number of pairs being displayed at the end of each entry, the cumulated probabilities are shown; thus, the number 1 should be seen at the conclusion of all entries. A press of [i] will then output the mean, and sigma will be found in the Y-register. (It should be noted throughout that, as with ZP, the HP Y-register replaces the TI T-register always).

Of course, the random number generator output will differ here, just as was the case in ZP. The same HP user instructions apply here, however. Thus, the generator is initialized by pressing [I] as before and you are prompted for a seed. The subroutine RNDMU, assigned to [H], will replace the TI [D.MS] routine to output a number between 0 and 1. If you will use a seed of .49 instead of 49 in the example treated on page 18, the HP output will be .5014, with a second application yielding .2349. A second program, called RNDMAB (assigned to [h]) replaces Steps 4-6 of ST-02 to output a (continuous) random number between A and B, provided A and B are stored in registers 13 and 14, respectively. For the example, again on page 18, using A=10 and B=67, the respective values will be 16.0050, 59.2222, 16.6282 and 24.0426. Finally, the subroutine RNDMI, assigned to [g], will generate random labels. On page 19 using a seed of .21, successive presses of [g] will produce labels 45, 53, 11 and 20. That will take care of the problems for this section. The answers will differ from those published of course. Be sure to press [J] when you wish to return to the main programs in ZS-2.

### Section 2.4: Simulating Continuous Distributions

In Example 2.3, if a seed of .635 is used, the successive values of  $u$  are: .5464, .1799, .9504, .6085, .7613, yielding  $x$  values of 791, 198, 3004, 938 and 1435, respectively. The program instructions at Step E5 should be modified according to the ones provided here.

Program ST-19 may be replaced entirely by using the N routine in ZS-2 with  $\mu = 0$  and  $\sigma = 1$ . (For that matter,  $P(z)$  may be found here by entering  $z$  and pressing [XEQ] 19, to mimic the TI program). Alternatively, program ENORMD in STAT PAC may be used to calculate  $Q(z)$ . Try  $z = 2.695$  as on page 24

to see that .9964 is the value of  $P(z)$ . The value  $Q(z) = .0036$  will then be found in the Y-register. Generating random samples from both the exponential and normal distributions has been automated in ZS-2 just as in the TI case and examples follow the user instructions. No further checks will be given here.

#### Section 2.5: Bernoulli Trials

As with ST-19, we have mimicked the TI binomial program ST-20 as subroutine 20 here. The instructions are given under the code BIN in ZS-2 and that program may be used to check all of the problems of this section. It might be noted that the standard deviation is found in the Y-register, pressing [ $X \leftrightarrow Y$ ] after [a], rather than a separate label [B'], as with TI.

ZS-2 (Assigned [J])		USER INSTRUCTIONS (HP)		SIZE $\geq$ 030
				$\Sigma$ REG 01
STEP	PROCEDURE	ENTER	PRESS	DISPLAY
E	<u>Exponential Distribution</u>			
1.	Initialization		[J]	0.0000
2.	Enter Parameter	$\lambda$	[STO]16	$\lambda$
3.	Compute $P(x)$ and $Q(x)$ Note: $\lambda x$ must not exceed 228	$x$	[E] [X<>Y]	$P(x)$ $Q(x)$
4.	Calculate 100(1- $\alpha$ )th Percentile Note: Repeat $E_3$ and $E_4$ at will.	$\alpha$	[e]	$x_\alpha$
5.	Generate sample of size $n$			
a.	Initialize Random Number Generator		[I]	SEED?
b.	Enter Seed ( $0 \leq \text{Seed} < 1$ )	Seed	[R/S]	Seed
c.	Execute Step E2			
d.	Generate $x$ (Repeat $n$ times)		[B]	$x$
N	<u>Normal Distribution</u>			
1.	Initialization		[J]	0.0000
2.	Enter Parameters	$\mu$	[STO]17	$\mu$
		$\sigma$	[STO]18	$\sigma$
3.	Compute $P(x)$ and $Q(x)$	$x$	[C] [X<>Y]	$P(x)$ $Q(x)$
4.	Compute $\Pr(x_1 < X < x_2)$ or $1 - P(x_1 < X < x_2)$			
a.	Enter $x_1$	$x_1$	[D]	$Q(x_1)$
b.	Enter $x_2$ and compute	$x_2$	[R/S] [X<>Y]	$\Pr(x_1 < X < x_2)$ $\Pr(X < x_1) +$ $\Pr(X > x_2)$
5.	Calculate Standard 100(1- $\alpha$ )th Percentile	$\alpha$	[c]	$z_\alpha$
6.	Calculate General 100(1- $\alpha$ )th Percentile Note: Repeat $N_3 - N_6$ as often as desired	$\alpha$	[d]	$x_\alpha$
7.	Generate sample of size $n$			
a.	Initialize Random Number Generator		[I]	SEED?
b.	Enter Seed ( $0 \leq \text{Seed} < 1$ )	Seed	[R/S]	Seed
c.	Execute Step N1			
d.	Generate $x$ (Repeat $n$ times)		[b]	$x$
8.	Standard Normal (TI ST-19)	$z$	[XEO]19 [X<>Y]	$P(z)$ $Q(z)$

ZS-2		USER INSTRUCTIONS			2.
STEP	PROCEDURE	ENTER	PRESS	DISPLAY	
BIN	<u>Binomial Distribution</u> (TI ST-20)				
1.	Initialize		[XEQ]20	PMTERS?	
2.	Enter Parameters	n	[R/S]	n	
		p	[R/S]	0.0000	
3.	Calculate probabilities	k	[A]	p(k)	
			[R+]	P(k)	
			[R+]	Q(k)	
MU-SIG	<u>Discrete Moments</u>				
1.	Initialize		[j]	ΣBSTG	
2.	Enter discrete pairs (Repeat i=1,...,N)	$x_i$	[ENTER]	$x_i$	
		$p_i$	[A]	$\Sigma p_i$	
3.	Calculate $\mu$ and $\sigma$ .		[i]	$\mu$	
			[X<>Y]	$\sigma$	
MOM	<u>Recall Moments</u>				
			[a]	$\mu$	
			[X<>Y]	$\sigma$	
<u>Register Contents</u>					
00	Used	10	K(label)	20	$z = (x-\mu)/\sigma$
01	Used by $\Sigma^+$	11		21	n
02		12		22	p
03		13	A	23	1-p
04		14	B	24	Used
05		15		25	Used
06		16	$\lambda$	26	
07	P(x)	17	$\mu$	27	
08	$P(x_1) - P(x_2)$	18	$\sigma$	28	
09	Seed	19	$z_\alpha$	29	

<u>Assignments</u>		<u>Labels Used</u>		
ZS-2	J	03	A	a
GEN-INI	I	06	B	b
RNDMU	H	07	C	c
RNDMAB	h	08	D	d
RNDMI	g	09	E	e
BSTG	j	11		
MU-SIG	i	12		
XBAR	P→R	19		
SD	R→P	20		
RD	R↓			



# EXAMPLES ZS-2.

1. Let  $X$  have an exponential distribution with parameter  $\lambda = 0.001$  and suppose  $X$  measures time to failure in hours.
  - (a) Calculate the probability that time to failure will exceed 1200 hours.
  - (b) Compare the mean time to failure with the median time to failure.
  - (c) How many hours may we reasonably depend upon for survival of 90% of such items?
  - (d) Generate a random sample of five times to failure.

## SOLUTIONS:

<u>ZP STEP</u>	<u>ENTER</u>	<u>PRESS</u>	<u>DISPLAY</u>	<u>COMMENTS</u>
E1		[J]	0.0000	Initialize the exponential subrou
E2	0.001	[STO]16	0.0010	Single parameter $\lambda$ stored in $R_{16}$
E3	1200	[E]	0.6988	Displays $P(1200) = \Pr(X \leq 1200)$ .
		[X<>Y]	0.3012	Displays $Q(1200) = \Pr(X \geq 1200)$ which is the answer to (a).
E4	.50	[e]	693.1472	Calculates and displays the median $x_{.50}$ (in hours).
		[RCL]17	1000.0000	Recall $\mu$ , the mean time to failure. This answers (b).
E4	.10	[e]	105.3605	Displays $x_{.90}$
E5a		[I]	SEED?	Initialize the random no. generator
E5b	.635	[R/S]	0.6350	Enter Seed = 635 for illustrative purposes.
E5c	(0.001)	([STO]16)	(0.001)	Enter the parameter $\lambda$ if not already entered.
E5d		[B]	790	Displays the first generated sample value, $x_1$ (rounded).
		[B]	198	The second simulated time to failure
		[B]	3003	Successive times to failure (rounded to whole hours) for a random sample of size 5.
		[B]	938	
		[B]	1432	

<u>ZS STEP</u>	<u>ENTER</u>	<u>PRESS</u>	<u>DISPLAY</u>	<u>COMMENTS</u>
(2) A standardized test is administered to incoming freshmen at a university. Scores, $X$ , are assumed to be normally distributed and, based on thousands of past scores, it is assumed that $\mu = 100$ and $\sigma = 16$ . For an incoming freshman chosen at random what is the probability that the test score will be:				
a) greater than 110? b) less than 90? c) between 75 and 125?				
If only the top 80% of incoming freshmen are to be admitted on the basis of this test, what would the minimum passing score be?				
<u>Solutions:</u>				
N1		[J]	0.0000	Initialize.
N2	100	[STO]17	100.0000	Enter the mean value.
"	16	[STO]18	16.0000	Enter the second parameter $\sigma$ .
N3	110	[C]	0.7340	Displays $P(110) = \Pr(X < 110)$ .
		[X<>Y]	0.2660	Displays $Q(110)$ , the required probability.
		[RCL]20	0.6250	Shows the standardized value for $x = 110$ , namely, $z = (110-100)/16$ .
N3	90	[C]	0.2660	Displays $P(90)$ .
N4a	75	[D]	0.9409	Displays $Q(75)$ , of minor interest.
N4b	125	[R/S]	0.8818	Calculates and displays $\Pr(75 < X < 125)$ .
		[X<>Y]	0.1182	Displays $\Pr(X < 75) + \Pr(X > 125)$ .
N6	.80	[d]	86.5367	Displays the 20th percentile for $X$ , so that $\Pr(X > 87) = 0.80$ .
(3) Generate a random sample of size 5 from a normal distribution				
N7a		[I]	SEED?	Initialize random number generator.
N7b	.198	[R/S]	0.1980	Enter Seed = 198 for illustrative purposes
N7c	50	[STO]17	50.0000	Enter the normal parameters
	10	[STO]18	10.0000	and store in appropriate registers.
N7d		[b]	42.63	Displays first generated sample value $x_1$ (rounded).
		[b]	56.34	Successive sample values
		[b]	63.21	are generated and
		[b]	72.72	displayed (rounded).
		[b]	46.84	

<u>ZS STEP</u>	<u>ENTER</u>	<u>PRESS</u>	<u>DISPLAY</u>	<u>COMMENTS</u>
(4) Find the mean and standard deviation of the discrete probability distribution.				
	x:	4.0    3.0    2.0    1.0    0.0		
	p(x):	0.13   0.21   0.43   0.14   0.09		
<u>SOLUTION:</u>				
MU-SIG 1.		[j]	ΣBSTG	Initialize module to start program
MU-SIG 2.	4	[ENTER]	4.00	Enter distribution as data
	.13	[A]	0.13	pairs( $x_i, p_i$ ) $i = 1, 2, \dots, n$ .
	3	[ENTER]	3.00	See $\Sigma p_i$ accumulated in $R_X$ with
	.21	[A]	0.34	1 indicating final data entry.
	2	[ENTER]	2.00	
	.43	[A]	0.77	
	1	[ENTER]	1.00	
	.14	[A]	0.91	
	0	[ENTER]	0.00	
	.09	[A]	1.00	
MU-SIG 3.		[i]	2.1500	Displays $\mu$ .
		[X<>Y]	1.0989	Displays $\sigma$ from $R_Y$ .

(5) Example 2-7.

SOLUTION:

BIN 1.		[XEQ] 20	PMTERS?	Initialize binomial program. Prompt is for n and p.
BIN 2.	4	[R/S]	4.0000	
	.51	[R/S]	0.0000	Parameter entry complete.
BIN 3.	0	[A]	0.0576	Display $P = p(0) = \Pr(Y=0)$ .
"	2	[A]	0.3747	Display is $p(2)$ so $P(2)$ is found
		[R+]	0.6724	in $R_Y$ .
		[R+]	0.3267	$Q(2)$ is found in $R_Z$ .
"	1	[A]	0.2400	$p(1)$ is displayed.
MOM		[a]	2.0400	Displays $\mu = np$
		[X<>Y]	0.9998	Displays $\sigma = npq$
		[USER] [ $x^2$ ]	0.9996	Calculates $\sigma^2$ .

## Chapter 3 Data Processing

This chapter is rather independent of the others and, as the name suggests, deals with the processing of numerical data to produce traditional statistical summaries as well as grouping data into different patterns. Three programs have been created for this purpose, ZS-3 and two separate ones that are revisions of corresponding TI programs ST-03, ST-07 and ST-09. The latter were created and so named in order to follow the textbook material with the least amount of revision of instructions. The three programs should be loaded simultaneously for solving the problems here. Since some partitioning (using the SIZE function) may be called for, it is advisable that all other programs be cleared from calculator memory. The labels to which the programs have been assigned make it very convenient to move from one to the other when necessary.

### Section 3.1: Sample Characteristics

Picking up the discussion on page 41, the HP, like the TI, is hard wired to compute means and standard deviations when data are entered on the keyboard with the  $\Sigma +$  key. Consult the Owner's Handbook for details. The basic differences are that (be sure you are not in USER mode) the registers are cleared with the CL $\Sigma$  key rather than using Pgm 01 and you execute the functions MEAN and SDEV instead of  $[\bar{x}]$  and  $[INV][\bar{x}]$ , respectively. Even so, the TI program ST-03, here assigned to [I], will allow for data storage as it does in the TI module. You see from the User Instructions that follow, you must initialize by pressing [e] and then enter the data one-by-one using label [A]. At the conclusion you will find the data stored beginning in register 31. In addition, you may press [P $\rightarrow$ R] in place of TI  $[\bar{x}]$  and use [R $\rightarrow$ P] instead of TI  $[INV][\bar{x}]$ . To find the range, press [J] to enter program ZS-03 and then press [C] as per the instructions for that program. (Do not forget to press [I] again if you wish to return to ST-03 for any reason.) The remarks regarding repartitioning may be easily transferred to appropriate remarks using the SIZE function for the HP. When data have been entered using program ST-03, you may find MSD by pressing [ENG] (the key that the subroutine MSD has been assigned to). MAD is computed by pressing [J] to enter ZS-03 and then press [B]. In this way, these instructions practically follow those of the TI to the letter. Verify the solution on page 47 for Example 3.1 following these instructions.

### Section 3.2: Grouping Data

Data are grouped and recovered in cells suitable for histogram construction by means of program ST-07/9 (assigned to label [i]), a program resembling the corresponding TI programs ST-07 and ST-09 discussed in the book. The same remarks regarding conventions and parameter limitations discussed on pages 52 and 53 apply here as well.

After pressing [i] to enter the program, you initialize with [e] just as with the TI program, only here you will be prompted for the number of cells. When you enter that number with a press of [R/S] you will then be prompted for lowest class limit XMIN and, after entering that, for the width, w, of each cell. These instructions conform to the TI instructions. At this point you have two options. If data have been entered previously, either with program ST-03 or with ST-07 itself, you have merely to press [d] whereupon you are prompted for the sample size n. Entering this number and pressing [R/S] causes the program to automatically group the data into cells as per the entry

in steps P1,2,3. Otherwise, you enter the data one-by-one using [A] just as with ST-03. Once the data have been entered, the histogram is constructed by the steps under code H. After initializing with [E], the successive cell frequencies and boundaries are displayed with a STOP at the end to signal completion of the display. This replaces the discussion on pages 53 and 54 of the text.

As for computing grouped moments, the version of ST-03 presented here is initialized the same way ([e]), and pairs are entered as discussed under code G (same as the TI entry). Moments are then displayed in the X-register when XBAR ([P+R]), SD(R+P]) and MSD ([ENG]) are used. You may then proceed to ZS-3 to find MAD and the range as discussed on page 55. The last two paragraphs on that page may be safely ignored.

### Section 3.3: Transformations

Step 5 of ZS-3 presented here allows for data transformations just as with the TI version. As with ZP programs, it may be advisable now and then to erase some of the algorithms used in [a] to create transformations if many applications happen to be used. Again, the DEL function will have to be used and this should be assigned to [g] if many such erasures will be taking place. You may also have to repartition your calculator with the SIZE function if there is no room for the data. For the small data sets illustrated here, that situation is not likely to arise. The answers to the problems given at the end of the section may all be verified with the program instructions on the following page.

### Section 3.4: The Central Limit Theorem

The program ENORMD in STAT PAC will have to be used in this section in place of ST-19, or, as remarked on page 63, you may use ZS-2 with the caution mentioned there. Since there is no binomial program in STAT PAC, the latter might be the advisable thing to do for resolving some of the problems in this section.





ST-03 (Assigned [I])		USER INSTRUCTIONS (HP)		SIZE 060-089	
				Σ REG 01	
STEP	PROCEDURE	ENTER	PRESS	DISPLAY	
I	Initialization		[e]	0.0000	
U	Ungrouped Data Entry Repeat i = 1,2,...,n.	$x_i$	[A]	i.0000	
G	Grouped Data Entry Repeat i = 1,2,...,n.	$f_i$ $x_i$	[B] [A]	$f_i$ i.0000	
MOM	1. Calculate sample mean and sample Standard Deviation  2. Calculate MSD		[P→R] [R→P]  [ENG]	$\bar{x}$  MSD	

REGISTER CONTENTS (Grouped data in parentheses)

00	Used	10	$1(f_i)$	20	30	Pointer
01	$\Sigma x(\Sigma f x)$	11	w	21	31	$x_1(x_1)$
02	$\Sigma x^2(\Sigma f x^2)$	12	$x_{\min}$	22	32	$x_2(f_1)$
03		13	$x_{\max}$	23	33	$x_3(x_2)$
04		14	Used	24	34	$x_4(f_2)$
05		15		25	35	.
06	$n(\Sigma f_i)$	16		26	36	:
07	$\Sigma  x_i - \bar{x} $	17		27	37	
08	Used	18	Used	28	38	
09	Lastx	19	xcount	29	39	

Assignments		Labels Used		
ZS-3	J	ZS-3	ST-03	ST-07/9
ST-03	I	01 A a	01 A e	01 A c
ST-07/9	i	02 B b	02 B	02 E d
XBAR	P→R	03 C c	03	03 e
SD	R→P	04 D d		04
MSD	ENG	05 E e		
		12		
		13		



ST-07/9 (Assigned [i])		USER INSTRUCTIONS		SIZE 060-089	
				Σ REG 01	
STEP	PROCEDURE	ENTER	PRESS	DISPLAY	
[i]	Initialization		[i]	0.0000	
2	Enter Parameters		[e]	CELLS?	
	1. Enter number of cells ( <u>≤</u> 15)	Cells	[R/S]	XMIN?	
	2. Enter Lowest Class Limit	$x_{\min}$	[R/S]	W = ?	
	3. Enter Interval Width	w	[R/S]	0.0000	
DE	Data Entry and Compilation				
1.	Original Data (Repeat i = 1,2,...,n)	$x_i$	[A]	i.0000	
	OR:				
2.	If Data Are Previously Stored		[d]	N = ?	
		n	[R/S]	n.0000	
H	Histogram Construction (after DE)				
1.	Initialization		[E]	0.0000	
	2. Display Cell Frequency		[c]	$f_i$	
	3. Display Upper Limit, $B_i$ , of Interval (Repeat i = 1,2,...,Cells)		[R/S]	$B_i$	
				⋮	⋮
				STOP	
<u>Note:</u> Ungrouped moments after DE may be computed by XBAR, SD and MSD in ZS-3. Corresponding grouped moments are then found in $R_y$ if Histogram has been constructed. In either case, you must press [i] again to return to ST-07/9.					

#### REGISTER CONTENTS

00	Used	10	Used	20	$f_7$	30	Pointer
01	$\Sigma x_{i_2}$	11	w	21	$f_8$	31	$x_1$
02	$\Sigma x_i$	12	$x_{\min}$	22	$f_9$	32	$x_2$
03	$\Sigma f_i x_{i_2}$	13	$x_{\max}$	23	$f_{10}$	33	$x_3$
04	$\Sigma f_i x_i$	14	$f_1$	24	$f_{11}$	34	$\vdots$
05	Used	15	$f_2$	25	$f_{12}$	35	$\vdots$
06	n	16	$f_3$	26	$f_{13}$	36	
07	Used	17	$f_4$	27	$f_{14}$	37	
08	Used	18	$f_5$	28	$f_{15}$	38	
09	CELLS	19	$f_6$	29	xcount	39	

# EXAMPLES ZS-3

- For the ungrouped data below, calculate  $\bar{x}$ , s, MSD, MAD and R. Then transform the data by  $x' = 1/x$  and calculate the same statistics for the transformed data.

5, 10, 6, 4, 3, 8, 12

Recall the actual values of the first three data points.

ZS STEP	ENTER	PRESS	DISPLAY	COMMENTS
ST-03		[I]	0.0000	Select ST-03
I		[e]	0.0000	Initialize for data entry.
U	5	[A]	1.0000	Enter data.
	10	[A]	2.0000	
	6	[A]	3.0000	
	4	[A]	4.0000	
	3	[A]	5.0000	
	8	[A]	6.0000	
	12	[A]	7.0000	Data Entry complete.
		[P→R]	6.8571	The value of the sample mean.
		[R→P]	3.2878	The value of the sample standard deviation.
		[ENG]	9.2653	Value of MSD.
ZS-3		[J]	9.2653	Enter program ZS-03.
3.		[B]	2.6939	MAD calculated and displayed.
1.		[C]	9.0000	The range R = 9
5a.		[e]	0.0000	Initialize ZS-3 for data transformation.
5b.		[GTO][a][PRGM]	160 LBLa	Preparation for transformation.
5c.		[1/x]	161 1/x	Simple algorithm.
"		[RTN]	162 RTN	Necessary return instruction.
"		[PRGM]	x.xxxx	Exit program mode for ZS-3 operation.
5d.(2)	7	[E]	7.0000	Data automatically transformed and stored in $R_{31}$ , $R_{32}$ , ... .
		[P→R]	0.1798	Value of $\bar{x}'$ rounded.
		[R→P]	0.0892	Rounded value of $s'$ .
		[ENG]	0.0068	Rounded value of MSD'.
3.		[B]	0.0697	Rounded value of MAD'.
1.		[C]	0.2500	Value of $R'$ , the new range.
6.		[d]	0.0000	Initialize to recall transformed data.

<u>ZS STEP</u>	<u>ENTER</u>	<u>PRESS</u>	<u>DISPLAY</u>	<u>COMMENTS</u>
		[D]	0.2000	Recall value of $x'_1 = 1/x_1$ .
		[D]	0.10000	Recall value of $x'_2 = 1/x_2$ .
		[D]	0.1667	Recall value of $x'_3 = 1/x_3$ .
		[CF]01	0.1667	Clear display program

2. For the grouped data below, calculate  $\bar{x}$ , s, MSD, MAD and the range.

Frequency:	3	4	9	4	5
Class					
Interval:	0-10	10-20	20-30	30-40	40-50

SOLUTION:

ST-03		[I]	0.0000	Select program ST-03.
I		[e]	0.0000	Initialize ST-03 for data entry.
G	3	[B]	3.0000	Enter first frequency.
	5	[A]	1.0000	Enter first midpoint; running count
	4	[B]	4.0000	displayed.
	15	[A]	2.0000	Repeat for each pair.
	9	[B]	9.0000	
	25	[A]	3.0000	
	4	[B]	4.0000	
	35	[A]	4.0000	
	5	[B]	5.0000	
	45	[A]	5.0000	Data entry concluded.
		[P→R]	26.6000	Grouped mean value $\bar{x}$ .
		[R→P]	12.8062	Rounded value of s.
		[ENG]	157.4400	Value of MSD.
ZS-3		[J]	157.4400	Enter Program ZS-3
4.		[b]	10.0480	Value of MAD.
2.	10	[c]	50.0000	Value of grouped range R-based on a class width of 10.

3. Group the following data into a histogram consisting of 6 cells of width  $w = 10$  starting at  $x_{\min} = 70$ .

120	86	87	75	100	120	100	80
110	105	95	90	100	85	95	85

Calculate:  $\bar{x}$ , s, MSD for both grouped and ungrouped data.

SOLUTION:

ST-07/9		[i]	0.0000	Select program ST-07-9
I		[e]	CELLS?	Initialize for parameter entry.
P1	6	[R/S]	XMIN?	Enter total number of cells.
P2	70	[R/S]	W = ?	Enter $x_{\min}$ , lowest data limit.

<u>ZS STEP</u>	<u>ENTER</u>	<u>PRESS</u>	<u>DISPLAY</u>	<u>COMMENTS</u>
P3	10	[R/S]	0.0000	Enter cell width.
DE	120	[A]	1.0000	Enter first data value
	86	[A]	2.0000	Enter second data value
		⋮	⋮	⋮
	85	[A]	16.0000	Enter last data value
H1		[E]	0.0000	Initialize histogram display.
H2		[c]	1	First cell frequency
H3		[R/S]	80.0000	B <sub>1</sub> so Cell 1 runs from 70 to 80.
H2		[c]	5	Second cell frequency
H3		[R/S]	90.0000	B <sub>2</sub> establishing interval 80 to 90
H2		[c]	3	Third cell frequency
H3		[R/S]	100.0000	Third cell upper limit.
H2		[c]	4	Fourth cell frequency
H3		[R/S]	110.0000	Fourth cell boundary.
H2		[c]	1	Fifth frequency for cell
H3		[R/S]	120.0000	running from 110 to 120
H2		[c]	2	Sixth frequency for last cell.
H3		[R/S]	130.0000	Upper bound on all data (not included as a possible value)
		[c]	STOP	Indicates conclusion of program.
		[P→R]	95.8125	$\bar{x}$ for ungrouped data
		[X<>Y]	98.1250	$\bar{x}$ for grouped data
		[R→P]	13.2525	s for ungrouped data
		[X<>Y]	14.9304	s for grouped data
		[ENG]	164.6523	MSD for ungrouped data
		[X<>Y]	208.9844	MSD for grouped data
		[i]	0.0000	Ensures return to ST-07/9

## Chapter 4 Estimation

## Chapter 5 Hypothesis Testing

The problems in both of these chapters are covered by a single program, called ZS-4/5. This was one of the more successful translations from TI to HP so that very little needs to be added in the way of remarks. As the reader will see from the User Instructions that follow, the directions are practically identical to those published in the text. One small difference is that raw data will not be entered by ST-03, but rather by a self-contained data entry scheme (DE) which is much simpler and covers all of the cases treated. Naturally, any TI reference to the T-register should be translated to the HP Y-register, and the display register,  $R_D$  referred to so often, becomes the HP X-register. Another important point that is universally true of the difference between the two calculators is that  $R_{06}$  is used by the HP routines for storing sample sizes while TI used  $R_{03}$ . That change should be noted throughout the instructions that follow.

As previously remarked, the program ZSTAT should be loaded into program memory for all of the ZS programs from this point on in the text. It will be convenient to assign ZSTAT to a label, say [SCI], for easy access to the programs that are referred to occasionally in these chapters.

On page 85 reference is made to the formula for the t-density in ASM. It is really not particularly instructive for the applications presented here to actually see the formula but it may be found in most standard textbooks, and a picture of the typical density is shown on page 103. In any case the value of the CDF  $P(t)$  may be found by storing degrees of freedom,  $v$ , in  $R_{15}$ , entering  $t$  and then [XEQ][TF] in ZSTAT. On page 86 it should be noted that the subroutine ZA in ZSTAT replaces the subroutine [sin] in TI. (See also the Note in the User Instructions that follow.)

One of the few distributions provided by STAT PAC is the Chi-square, referred to on page 92. This distribution is labeled  $\Sigma$ CHISOD and is discussed on page 70 of the STAT PAC handbook. It may also be found as the subroutine [CHISD] in ZSTAT (requiring, again, only that degrees of freedom be store in  $R_{15}$ ). Either replaces references to [C] in TI ST-21. A typical Chi-square density is depicted in the legend to Table C on page 104, where percentiles are located. It should be observed that the footnote regarding large degrees of freedom applies verbatim to the HP program ZS-4/5.

That takes care of all of the differences in these two chapters. Following the User Instructions on the next three pages will be found the typical model problems for verifying program output.

STEP	PROCEDURE	ENTER	PRESS	DISPLAY
DE	ORIGINAL DATA ENTRY			
1.	Enter Data			
	a. Initialize		[J]	DATA?
	b. $x_i$ Repeat $i = 1, 2, \dots, n$		[R/S]	i.0000
2.	Process Data for Storage		[d]	0.0000
N( $\mu$ )	<u>NORMAL MEAN - <math>\sigma</math> UNKNOWN</u>			
1.	Enter Data using DE <u>OR</u> :			
	a. Enter Sample Size	n	[STO]06	n
	b. Enter Sample Mean	$\bar{x}$	[STO]37	$\bar{x}$
	c. Enter Sample Standard Deviation	s	[STO]38	s
2.	<u>Test <math>H_0 : \mu = \mu_0</math></u>			
	a. Enter $H_1$ -code*	$H_1$ -code	[a]	$H_1$ -code
	b. Enter $\mu_0$ and Compute P-value	$\mu_0$	[R/S]	P
3.	<u>CI for <math>\mu</math></u>			
	a. Calculate Degrees of Freedom		[A]	v
	b. Enter $t_{\alpha/2}$ with d.f. = v and calculate limits	$t_{\alpha/2}$	[R/S] [X<>Y]	l u
NOTE: For One-sided intervals, enter $t_\alpha$ at Step 3b and ignore l or u as the case may be.				
N( $\mu \sigma$ )	<u>NORMAL MEAN - <math>\sigma</math> KNOWN</u>			
1.	Enter Data Using DE <u>OR</u> :			
	a. Enter Sample Size	n	[STO]06	n
	b. Enter Sample Mean	$\bar{x}$	[STO]37	$\bar{x}$
3.	<u>Test <math>H_0 : \mu = \mu_0</math></u>			
	a. Enter $H_1$ -Code	$H_1$ -code	[b]	$H_1$ -code
	b. Enter $\mu_0$ and Compute P-value	$\mu_0$	[R/S]	P
4.	Calculate $100(1-\alpha)\%$ <u>CI for <math>\mu</math></u>	$\alpha/2$	[B] [X<>Y]	l u
Note: Enter $\alpha$ for one-sided intervals and ignore l or u as the case may be.				

$$\begin{array}{lcl}
 * & 1 & \text{if } H_1 : \theta > \theta_0 \\
 H_1\text{-code} = & 0 & \text{if } H_1 : \theta \neq \theta_0 \\
 & -1 & \text{if } H_1 : \theta < \theta_0
 \end{array}$$

Note: In ZSTAT (assigned [SCI]),  
[XEQ][ZA] displays  $z_p$  if P is in  $R_X$



S-4/5 USER INSTRUCTIONS				
STEP	PROCEDURE	ENTER	PRESS	DISPLAY
1( $\sigma^2$ )	<u>NORMAL VARIANCE</u>			
1.	Enter Data Using DE <u>OR</u> :			
	a. Enter Sample Size	n	[STO]06	n
	b. Enter Sample Standard Deviation	s	[STO]38	s
2.	Test $H_0 : s^2 = \sigma_0^2$			
	a. Enter $H_1$ -code	$H_1$ -code	[c]	$H_1$ -code
	b. Enter $\sigma_0^2$ and Compute P-value	$\sigma_0^2$	[R/S]	P
3.	<u>CI for <math>\sigma^2</math></u>			
	a. Calculate Degrees of Freedom		[C]	v
	b. Enter Chi-square Percentiles			
	( $v=n-1$ ) and Calculate Limits	$\chi_{1-\alpha/2}^2$ $\chi_{\alpha/2}^2$	[STO]41 [STO]31 [R/S] [X<>Y]	$\chi_{1-\alpha/2}^2$ $\chi_{\alpha/2}^2$ l u
NOTE: For Upper One-sided Interval, enter $\chi_{1-\alpha}^2$ in $R_{41}$ and in $R_{31}$ and see u displayed. For Lower One-sided interval, enter $\chi_{\alpha}^2$ in $R_{31}$ and $R_{41}$ see see l displayed.				
Exp( $\mu$ )	<u>Exponential Mean</u>			
1.	Enter data using DE or:			
	a. Enter Sample Size	n	[STO]06	n
	b. Enter Sample Mean	$\bar{x}$	[STO]37	$\bar{x}$
2.	Test $H_0 : \mu = \mu_0$			
	a. Enter $H_1$ -code	$H_1$ -code	[e]	$H_1$ -code
	b. Enter $\mu_0$ and Compute P-value	$\mu_0$	[R/S]	P
3.	<u>CI for</u>			
	a. Calculate Degrees of Freedom		[E]	v
	b. Enter Chi-square Percentile $v=2n$			
	and Calculate Limits	$\chi_{1-\alpha/2}^2$ $\chi_{\alpha/2}^2$	[STO]41 [STO]31 [R/S] [X<>Y]	$\chi_{1-\alpha/2}^2$ $\chi_{\alpha/2}^2$ l u
NOTE: See Previous Note for One-Sided Intervals.				



# REGISTER CONTENTS

00		10		20		30	ts	40	$\theta$
01	$\Sigma x_i$	11		21		31	$t_{\alpha/2}, \chi^2_{\alpha/2}$	41	$\chi^2_{1-\alpha/2}$
02	$\Sigma x_i^2$	12		22		32	SE	42	
03		13		23		33	<u>Used</u>	43	
04		14	Used	24		34	$\theta_0$	44	
05		15	v	25		35		45	
06	n	16		26	<u>Used</u>	36		46	
07		17		27		37	$\bar{x}$	47	
08		18		28	$H_1$ -code	38	s	48	
09		19		29	P(ts)	39	e( $\theta \pm e$ )	49	Used

## Assignments

ZS-4/5 | J

## Labels Used

01 A a  
 02 B b  
 03 C c  
 04 D d  
 05 E e  
 06  
 07

# EXAMPLES ZS-4/5

- (1) To study the effects of a drug, nine athletes were timed in a series of physical tests and yielded an average of  $\bar{x} = 10.13$  minutes. It was assumed in the study that  $\sigma = 1$  and that reaction times are normally distributed.
  - a. Find a 90% CI for the mean reaction time  $\mu$ .
  - b. Determine a 99% lower one-sided interval for  $\mu$ .
  - c. Find a one-sided upper bound on  $\mu$  having risk 15%.
- (2) Four specimens of an expensive cloth were subjected to strength tests and the breaking strengths in lbs./sq. in. were recorded as 181, 173, 176, 175. The standard deviation based on past experience is 5 lbs./sq in. Assume normality.
  - a. Find a 95% CI for  $\mu$ , the mean breaking strength.
  - b. What is a lower one-sided bound for  $\mu$  with confidence 90%?

## Solution (1):

<u>ZP STEP</u>	<u>ENTER</u>	<u>PRESS</u>	<u>DISPLAY</u>	<u>COMMENTS</u>
N( $\mu \sigma$ ) 1a.	9	[STO]06	9.0000	Places the sample size in $R_{06}$ .
1b.	10.13	[STO]37	10.1300	Stores the sample average in $R_{37}$ .
2.	1	[STO]48	1.000	Stores known $\sigma$ -value in $R_{48}$ .
4.	.05	[B]	9.5816	Enter $\alpha/2 = .10/2$ ; display $\ell$ .
		[X<>Y]	10.6784	Exchange and display u. 90% CI for $\mu$ is (9.58, 10.68).
4.	.01	[B]	9.3544	Enter $\alpha = .01$ and find $\ell = 9.35$ so confidence is 99% that $\mu > 9.35$ solving (b) ( $R_Y$ is not examined)
4.	.15	[B]	9.78	Using $\alpha = .15$ , $\ell$ is calculated but ignored.
		[X<>Y]	10.4755	The Y-register yields required upper limit on $\mu$ , solving (c).

## Solution (2):

DE	1.	[J]	DATA?	
		[R/S]	0.0000	Initialize ZS-4 for data entry.
	181	[R/S]	1.0000	First breaking strength entered.
	173	[R/S]	2.0000	Second breaking strength entered.
	176	[R/S]	3.0000	Third breaking strength entered.
	175	[R/S]	4.0000	Fourth breaking strength entered.
DE	2.	[d]	0.0000	Data processed.
N( $\mu \sigma$ ) 2.	5	[STO]48	5.0000	Stores known $\sigma$ -value in $R_{48}$ .

<u>ZS STEP</u>	<u>ENTER</u>	<u>PRESS</u>	<u>DISPLAY</u>	<u>COMMENTS</u>
4.	.025	[B]	171.3490	Entering $\alpha/2$ for $\alpha = .05$ , 2 is displayed.
		[X<>Y]	181.1510	Y-register yields u. CI:(171.3, 181.1510) is reported and (a) is resolved.
4.	.10	[B]	173.0457	The 90% lower limit for (b) of 173.0457 is found using $\alpha = .10$ .

- (3) Five specimens of coke tested for porosity showed weight gains of 2.16, 2.19, 2.31, 2.30 and 2.21, all in pounds. The variance of the process is unknown. Find a 90% C.I. for the mean weight gain. Find estimates of  $\mu$  and  $\sigma$  and SE.

Solution:

DE	1.	[J]	DATA?	
		[R/S]	0.0000	Initialize ZS-4 Ungrouped for data entry.
	2.16	[R/S]	1.0000	First weight entered.
	2.19	[R/S]	2.0000	Successive weights entered.
	2.31	[R/S]	3.0000	
	2.30	[R/S]	4.0000	
	2.21	[R/S]	5.0000	
DE	2.	[d]	0.0000	Process data.
N( $\mu$ )	3a.	[A]	4.0000	Display $v = 4$ .
	3b.	2.132	[R/S]	2.1698 Lower confidence limit displayed
			[X<>Y]	2.2982 Upper Limit retrieved from $R_Y$ .
			[RCL]40	Retrieve $\hat{\mu} = \bar{x}$ , the estimate of $\mu$ .
			[RCL]38	Retrieve $\hat{\sigma}$ , the estimate of $\sigma$ .
			[RCL]32	Retrieve $s/\sqrt{n}$ , the estimate of SE.
Report $2.17 < \mu < 2.30$ or 90% C.I. for $\mu$ is (2.17, 2.30).				

- (4) Summary data for a problem are  $\bar{x} = 2.268$  and  $s = 0.225$ . Determine a 90% lower one-sided C.I. for  $\mu$  and an upper 99% C.I. for  $\mu$ .

Solution:

N( $\mu$ )	1a.	5	[STO]06	5.0000	Enter the sample size in $R_{03}$ .
	1b.	2.268	[STO]37	2.2680	Enter the sample average in $R_{40}$ .
	1c.	.225	[STO]38	0.2250	Enter the sample s.d. in $R_{38}$ .
	3a.		[A]	4.0000	Display $v = 4$ .
	3b.	1.533	[R/S]	2.1137	Lower limit is displayed; $R_Y$ ignored.
	3a.		[A]	4.	
	3b.	3.747	[R/S]	(1.890)	$t_{.01}$ entered and lower limit ignored.
			[X<>Y]	2.6450	$R_Y$ yields the upper one-sided limit.

<u>ZS STEP</u>	<u>ENTER</u>	<u>PRESS</u>	<u>DISPLAY</u>	<u>COMMENTS</u>
(7)	Times to failure for six expensive pieces of electronic equipment were recorded in hours as 233.6, 1402.7, 3119.0, 612.9, 258.3 and 2211.2.			
(a)	Find a 95% C.I. for mean time to failure.			
(b)	Determine a point estimate and a lower one-sided 95% confidence limit on the reliability at 500 hrs.			

Solution:

DE	1.	[J]	DATA?	
		[R/S]	0.0000	Initialize ZS-4 for raw data entry.
	233.6	[R/S]	1.0000	First time to failure entered.
	1402.7	[R/S]	2.0000	Succeeding times to failure
	3119	[R/S]	3.0000	entered and processed.
	612.9	[R/S]	4.0000	
	258.3	[R/S]	5.0000	
	2211.2	[R/S]	6.0000	
DE	2.	[d]	0.0000	Data processed.
Exp( $\mu$ )	3a.	[E]	12.0000	Display $v = 2n$
	3b.	4.4	[STO]41 4.4	Storing lower percentile in $R_{41}$
		23.4	[STO]31 23.3	Storing upper percentile in $R_{31}$
			[R/S] 669.8889	Display $\hat{\lambda}$
			[X<>Y] 3562.5909	Find $u$ so CI is (673,3563)
			[RCL]40 1306.2833	$\hat{\mu} = \bar{x} = 1306$
			[U][1/x][U] 0.0008	$\hat{\lambda} = 1/\bar{x} = 0.0008$
	500	[x]	0.3828	Multiplying by 500 to find $500\hat{\lambda}$
		[CHS]	-0.3828	Change sign for exponentiation
			[U][e <sup>x</sup> ][U] 0.6820	to yield estimate of $R(500)$ .
			[E] 12.0000	Display $v$ to start new problem.
	21.0	[STO]31	21.0000	Store required $\chi^2_{.05}$ in $R_{31}$
		[STO]41	1.0000	and 1 in $R_{41}$ for one-sided limit.
			[R/S] 746.4476	Display required lower limit on $\mu$
			[U][1/x][U] 0.0013	Upper limit on $\lambda$
	500	[x]	0.6698	Multiplying by 500 to find upper limit on $-500\lambda$
			[CHS] -0.6698	Lower limit on $-500\lambda$
			[U][e <sup>x</sup> ][U] 0.5118	Lower bound on $R(500)$ .

NOTE: [U] stands for the [USER] key.

### Examples ZS-4 (Testing, Chapter 5)

- (1) Seven observations of measured radiation intensity at a nuclear plant were 3.6, 4.2, 4.0, 4.1, 3.8, 3.9, 4.0. Conduct a significance test of  $H_0 : \mu \leq 3.8$  against  $H_1 : \mu > 3.8$ .

Solution:

<u>ZS STEP</u>	<u>ENTER</u>	<u>PRESS</u>	<u>DISPLAY</u>	<u>COMMENTS</u>
DE 1		[J]	DATA?	Select and initialize ZS-4
	3.6	[R/S]	1.0000	} Enter Data
	4.2	[R/S]	2.0000	
	:			
	4.0	[R/S]	7.0000	
DE 2		[d]	0.0000	Process data.
N( $\mu$ ) 2a.	1	[a]	1.0000	Enter $H_1$ -code (+1).
2b.	3.8	[R/S]	0.0530	Enter boundary value and compute $P = .053$ from t-density.

- (2) A water meter has variance 14 (cu. ft)<sup>2</sup>. Twenty monthly readings indicate a sample mean of 1284 cu. ft. per month.

- (a) Test the hypothesis  $H_0 : \mu = 1286$  against  $H_1 : \mu \neq 1286$ , using  $\alpha = .05$ .
- (b) Calculate the significance level for the one sided alternative  $H_1' : \mu < 1286$ .

Solution:

N( $\mu \sigma$ )1a	20	[STO]06	20.0000	Enter sample size.
N( $\mu \sigma$ )1b	1284	[STO]37	1284.0000	Enter sample average.
N( $\mu \sigma$ )1c	14	[ $\sqrt{x}$ ][STO]48	3.7417	Enter known $\sigma$ .
N( $\mu \sigma$ )4	.025	[B]	1284.3598	$\ell$
		[X<>Y]	1285.6402	$u$ (Since $(\ell, u)$ does not contain $\mu_0$ , $H_0$ is rejected.)
N( $\mu \sigma$ )3a	-1	[b]	-1.0000	$H_1$ -code for part (b).
N( $\mu \sigma$ )3b	1286	[R/S]	0.0084	P-value (data are inconsistent with $H_0$ ).

<u>ZS STEP</u>	<u>ENTER</u>	<u>PRESS</u>	<u>DISPLAY</u>	<u>COMMENTS</u>
(3)	The standard deviation in GRE scores nationwide has been 40 points. The GRE scores for 86 Smith High School students this year has (sample) standard deviation 35.2. What is the significance of this result?			

Solution:

$N(\sigma^2)$	1a.	86	[STO]06	86.0000	Enter sample size.
$N(\sigma^2)$	1b.	35.2	[STO]38	35.2000	Enter sample standard deviation.
$N(\sigma^2)$	2a.	0	[c]	0.0000	Enter $H_1$ -code for $H_1 : \sigma \neq 40$ .
$N(\sigma^2)$	2b.	1600	[R/S]	0.1220	P-value. (Data are somewhat consistent with $H_0 : \sigma = 40$ .)

- (4) Times to failure of a sample of 12 unused D-cells were (in weeks):  
27, 41, 29, 33, 30, 33, 26, 37, 29, 11, 20, 29. The shelf life is  
claimed to be at least 35 weeks. Conduct a significance test of  
 $H_0 : \mu \leq 35$  vs.  $H_1 : \mu > 35$ .

Solution:

DE	1		[J]	DATA?	Select and initialize ZS-4.
			[R/S]	0.0000	
	27		[R/S]	1.0000	} Enter data
	41		[R/S]	2.0000	
	:		:	:	
	29		[R/S]	12.0000	
DE	2		[d]	0.0000	Process data.
Exp( $\mu$ )	2a.	1	[e]	1.0000	Enter $H_1$ -code
Exp( $\mu$ )	35		[R/S]	0.7129	P-value (data are consistent with $H_0$ .)



## Chapter 6 Bivariate Populations

Program ZS-6 is another very successful transfer from the TI version and is assigned to [J] which also serves to initialize data entry and will ultimately replace references to ST-04. For matters discussed in Section 6.2, however, it is more convenient to use the program  $\Sigma$ BSTAT in STAT PAC. The procedure for inputting paired data is discussed on page 11 of the STAT PAC handbook. Output is then displayed by successive [R/S]'s, some of which are of no interest here. It should be noted that the output labeled GXY is simply the correlation coefficient referred to on page 130 of ZS. Also, in the notation of ZS, the HP output labeled SX. is RMSD for X, while SY. is RMSD for Y.

The STAT PAC program  $\Sigma$ BSTAT does not appear to be suitable for entering independent data of the type discussed on page 131 of ZS. Nor is any provision made for entering univariate data in any of the programs published in STAT PAC. The simplest solution is to start with the x-data and enter the data twice at Step 2 (that is, let  $y_i = x_i$ ) in BSTAT, in which case all of the moments are X-moments and the correlation is 1; alternatively, the [ENTER] portion of Step 2 may be ignored, each  $x$  entered with [A] in which case you should ignore all X-outputs in the list and copy only those for Y and ignore GXY altogether. Then the whole process needs to be repeated for the y-data.

### Section 6.3; Paired Data

For implementation of the programs in ZS-6, raw data will be entered via a self-contained subroutine, called DE in the User Instructions that follow, and replaces references to ST-04 in the rest of the chapter. That subroutine is divided into two parts depending on whether the data are paired or independent. For this section, the data are paired so that option P will be used and the user instructions make it clear how the data are to be entered. Be sure to process the data after entry by pressing [d]. Otherwise, the instructions are identical to those provided in the book for TI.

### Section 6.4: Independent Data

In this section the I option of data entry DE is to be used and, at the conclusion of data entry once more [d] must be used to process the data. Please keep in mind also that  $R_{06}$  is to be used in place of TI  $R_{03}$  throughout. The rest of the instructions are identical.

### Section 6.5: Equality of Variances

No F-distribution is provided by STAT PAC so that distribution has been programmed into ZSTAT. Again, no formula is provided in ZS, nor is one really needed in this context. But the subroutine FCDF in ZSTAT will output  $P(F)$ , while FCCDF will output  $Q(F)$  provided  $v_1$  is in  $R_{15}$  and  $v_2$  is in  $R_{16}$ . For example, if  $v_1 = 2$  and  $v_2 = 24$ , you may verify by executing FCCDF in ZSTAT that  $Q(2.63) = .0927$ ; if  $v_1 = 20$  and  $v_2 = 7$ , then  $P(.4) = .0510$ . Again, the rest of the remarks in the book apply to the HP programs verbatim.



STEP	PROCEDURE	ENTER	PRESS	DISPLAY
DE	ORIGINAL DATA ENTRY			
0.	Initialize		[J]	DATA?
1.	Enter Data			
	a. Paired Data		[P]	0.0000
	(Repeat $i = 1, 2, \dots, n$ )	$x_i$	[ENTER]	$x_i$
		$y_i$	[R/S]	i.0000
	b. Independent Data		[I]	0.0000
	(1) Repeat $i = 1, 2, \dots, n_x$	$x_i$	[R/S]	i.0000
			[j]	0.000
	(2) Repeat $j = 1, 2, \dots, n_y$	$y_j$	[R/S]	
2.	Process Data		[d]	0.0000
PN	Paired Data: $\mu_x - \mu_y$			
1.	Enter Data Using DE OR:			
	a. Enter Sample Size	n	[STO]006	n
	b. Enter Sample Means			
	(1) Original Means	$\bar{x}$	[STO]47	$\bar{x}$
	OR:	$\bar{y}$	[STO]37	$\bar{y}$
	(2) Mean Difference	$\bar{d}$	[STO]47	$\bar{d}$
		0	[STO]37	0
	c. Enter Sample Standard Deviation	$s_d$	[STO]27	$s_d$
2.	Test $H_0 : \mu_x - \mu_y = \theta_0$			
	a. Enter $H_1$ -code*	$H_1$ -code	[b]	$H_1$ -code
	b. Enter $\theta_0$ and Computer P-value	$\theta_0$	[R/S]	P
3.	CI for $\mu_x - \mu_y$			
	a. Calculate degrees of freedom		[B]	$\nu$
	b. Enter $t_{\alpha/2}$ with d.f. = $\nu$ and Calculate Limits	$t_{\alpha/2}$	[R/S] [X<>Y]	$\ell$ u

Note: For one-sided intervals, enter  $t_\alpha$  at 3b and ignore  $\ell$  or  $u$  as the case may be.

$$H_1\text{-code} = \begin{cases} 1 & \text{if } H_1 : \theta > \theta_0 \\ 0 & \text{if } H_1 : \theta \neq \theta_0 \\ -1 & \text{if } H_1 : \theta < \theta_0 \end{cases}$$

STEP	PROCEDURE	ENTER	PRESS	DISPLAY
INA $(\sigma_x = \sigma_y)$	Independent Data: $\mu_x - \mu_y$			
	1. Enter data Using DE OR: Clear Memory and		[J]	DATA?
	a. Enter Sample Sizes	$n_x$	[STO]13	$n_x$
		$n_y$	[STO]06	$n_y$
	b. Enter Sample Averages	$\bar{x}$	[STO]47	$\bar{x}$
		$\bar{y}$	[STO]37	$\bar{y}$
	c. Enter Standard Deviation			
	(1) Pooled Estimate Available OR:	$s_p$	[STO]33	$s_p$
	(2) Original S.D.'s Available	$s_x$	[STO]48	$s_x$
		$s_y$	[STO]38	$s_y$
2.	Test $H_0 : \mu_x - \mu_y = \theta_0$			
	a. Enter $H_1$ -Code	$H_1$ -code	[c]	$H_1$ -code
	b. Enter $\theta_0$ and Compute P-value	$\theta_0$	[R/S]	P
3.	CI for $\mu_x - \mu_y$			
	a. Calculate degrees of freedom		[C]	$v$
	b. Enter $t_{\alpha/2}$ with d.f. = $v$	$t_{\alpha/2}$	[R/S]	$l$
	and Calculate Limits		[X<>Y]	$u$
See Previous Note for One-sided Limits.				
INB $(\sigma_x \neq \sigma_y)$	Independent Data: $\mu_x - \mu_y$			
	(Welch Approximate t)			
	1. Enter Data using DE OR:			
	a. Enter Sample Sizes	$n_x$	[STO]13	$n_x$
		$n_y$	[STO]06	$n_y$
	b. Enter Sample Means	$\bar{x}$	[STO]47	$\bar{x}$
		$\bar{y}$	[STO]37	$\bar{y}$
	c. Enter Sample Standard Deviations	$s_x$	[STO]48	$s_x$
		$s_y$	[STO]38	$s_y$

ZS-6		USER INSTRUCTIONS		3.
STEP	PROCEDURE	ENTER	PRESS	DISPLAY
2.	<u>Test <math>H_0 : \mu_x - \mu_y = \theta_0</math></u> a. Enter $H_1$ -code b. Enter $\theta_0$ and Compute P-value	$H_1$ -code $\theta_0$	[a] [R/S]	$H_1$ -code P
3.	<u>CI for <math>\mu_x - \mu_y</math></u> a. Calculate Degrees of Freedom b. Enter $t_{\alpha/2}$ with d.f. = $\nu$ and Calculate Limits	$t_{\alpha/2}$	[A] [R/S] [X<>Y]	$\nu$ $\ell$ u
See Previous Note for One-Sided Limits				
LSN	<u>LARGE SAMPLE NORMAL <math>\mu_x - \mu_y</math></u> <u>OR: <math>\sigma_x, \sigma_y</math> known</u>			
1.	Enter Summary Data Only: a. Enter Sample Sizes b. Enter Sample Means c. Enter Standard Deviations	$n_x$ $n_y$ $\bar{x}$ $\bar{y}$ $\sigma_x$ or $s_x$ $\sigma_y$ or $s_y$	[STO]13 [STO]06 [STO]47 [STO]37 [STO]48 [STO]38	$n_x$ $n_y$ $\bar{x}$ $\bar{y}$ $\sigma_x$ or $s_x$ $\sigma_y$ or $s_y$
2.	<u>Test <math>H_0 : \mu_x - \mu_y = \theta_0</math></u> a. Enter $H_1$ -code b. Set Flag 5 c. Enter Focal and Calculate P-value	$H_1$ -code $\theta_0$	[a] [SF]05 [R/S]	$H_1$ -code $H_1$ -code P
3.	<u>CI for <math>\mu_x - \mu_y</math></u> a. Initialize (Ignore output) b. Enter $z_{\alpha/2}$ and Calculate Limits	$z_{\alpha/2}$	[A] [R/S] [X<>Y]	xx $\ell$ u
See Previous Note for One-Sided Limits				

STEP	PROCEDURE	ENTER	PRESS	DISPLAY
NV	<u>Independent Data <math>\sigma_x^2/\sigma_y^2</math></u>			
1.	Enter Data using DE <u>OR</u> : a. Enter Sample Sizes b. Enter Sample Standard Deviations	$n_x$ $n_y$ $s_x$ $s_y$	[STO]13 [STO]06 [STO]48 [STO]38	$n_x$ $n_y$ $s_x$ $s_y$
2.	<u>Test <math>H_0 : \sigma_x^2 = \sigma_y^2</math></u> a. Enter $H_1$ -code; Set Flag 4. b. Calculate P-value	$H_1$ -code	[SF]04 [D]	$H_1$ -code P
3.	<u>CI for <math>\sigma_x^2/\sigma_y^2</math></u> a. Compute Degrees of Freedom From Accompanying Table: b. Enter F-value with d.f. = ( $v_1, v_2$ ) c. Enter F-value with d.f. = ( $v_2, v_1$ ) d. Calculate Limits	$F_{\alpha/2}$ $F_{\alpha/2}$	[D] [R/S] [STO]31 [STO]41 [R/S] [X<>Y]	$v_1$ $v_2$ $F_{\alpha/2}$ $F_{\alpha/2}$ $l$ u
<p>Note: a. For Lower One-Sided Interval, enter <math>F_\alpha</math> at Step 3b, 1 at Step 3c and ignore u.</p> <p>b. For Upper One-Sided Interval, enter 1 at Step 3b, <math>F_\alpha</math> at Step 3c and ignore <math>l</math>.</p>				
Exp	<u>Independent Exponential <math>\mu_x/\mu_y</math></u>			
1.	Enter Data Using DE <u>OR</u> : a. Enter Sample Sizes b. Enter Sample Means	$n_x$ $n_y$ $\bar{x}$ $\bar{y}$	[STO]13 [STO]06 [STO]47 [STO]37	$n_x$ $n_y$ $\bar{x}$ $\bar{y}$
2.	<u>Test <math>H_0 : \mu_x = \mu_y</math></u> a. Enter $H_1$ -code; Set Flag 4. b. Calculate P-value (See Note under NV2)	$H_1$ -code	[SF]04 [E]	$H_1$ -code P

TEP	PROCEDURE	ENTER	PRESS	DISPLAY
3.	CI for $\mu_x/\mu_y$ a. Compute Degrees of Freedom From Accompanying Table: b. Enter F-value with d.f. = $(v_1, v_2)$ c. Enter F-value with d.f. = $(v_2, v_1)$ d. Calculate Limits	$F_{\alpha/2}$ $F_{\alpha/2}$	[E] [R/S] [STO] 31 [STO] 41 [R/S] [X<>Y]	$v_1$ $v_2$ $F_{\alpha/2}$ $F_{\alpha/2}$ $l$ $u$

See Previous Note (NV) for One-Sided Limits

Register Contents

00	xxx	10	20	30	40	$\hat{\theta}$
01	$\Sigma y$	11	1	21	31	$t_{\alpha/2}, F_{\alpha/2}$
02	$\Sigma y^2$	12		22	32	SE
03	$\Sigma x$	Used	13	$n_x$	23	Used
04	$\Sigma x^2$		14	CCDF	24	
05	$\Sigma xy$		15	$v(v_1)$	25	
06	$n_y$		16	$v_2$	26	
07	Used		17	Used	27	$s_d$
08	Used		18		28	$H_1$ -code
09	Used		19		29	$P(ts)$
					33	$s_p$
					34	$\theta_0$
					35	
					36	
					37	$\bar{y}$
					38	$s_y$
					39	$e(\hat{\theta} \pm e)$
					41	$F_{\alpha/2}$
					42	
					43	
					44	
					45	
					46	
					47	$\bar{x}, \bar{d}$
					48	$s_x$
					49	

Assignments

ZS-6	J
DEP	P
DEI	I
OP11	ENG
X TO Y	j

Labels Used

00	A	a
01	B	b
02	C	c
04	D	d
05	E	
06		
08		
09		
11		
12		
13		

# Examples ZS-6

- (1) Before (X) and After (Y) weights were recorded in lbs. after two weeks of dieting. Find a 95% CI for the mean difference  $\mu_x - \mu_y$  and conduct a significance test of equality test of equality of means. Test for a weight loss of at least 2 lbs.

x:	119	122	136	130	129	136	134	133	119	115
y:	114	119	134	126	119	137	124	127	119	107

## Solution:

<u>ZS STEP</u>	<u>ENTER</u>	<u>PRESS</u>	<u>DISPLAY</u>	<u>COMMENTS</u>
DE 0.		[J]	DATA?	
1a.		[P]	0.0000	Initialize ZS-6 for paired data entry.
	119	[ENTER]	119.0000	Enter first x-value.
	114	[R/S]	1.0000	Follow with first y-value.
	122	[ENTER]	122.0000	Enter second x-value.
	119	[R/S]	2.0000	Follow with second y-value.
	136	[ENTER]	136.0000	Enter succeeding pairs.
	134	[R/S]	3.0000	
	130	[ENTER]	130.0000	
	126	[R/S]	4.0000	
	129	[ENTER]	129.0000	
	119	[R/S]	5.0000	
	136	[ENTER]	136.0000	
	137	[R/S]	6.0000	
	134	[ENTER]	134.0000	
	124	[R/S]	7.0000	
	133	[ENTER]	133.0000	
	127	[R/S]	8.0000	
	119	[ENTER]	119.0000	
	119	[R/S]	9.0000	
	115	[ENTER]	115.0000	Enter last x-value
	107	[R/S]	10.	Follow with last y-value (n = 10)
DE 2.		[d]	0.0000	ZS program processes data.
PN 3a.		[B]	9.0000	Calculates and displays $v = 9 = d$ .
3b.	2.262	[R/S]	1.9389	Enter $t_{.025}$ from t-table and display $t^* = 1.94$
		[X<>Y]	7.4611	Display u so CI is (1.94, 7.46).
PN 2a.	0	[b]	0.0000	Enter $H_1$ -code = 0 for two-sided test.



ZS STEP	ENTER	PRESS	DISPLAY	COMMENTS
PN 2a.	0	[R/S]	0.0039	Use $\theta_0 = 0$ for this case and find $P = 0.0039$ ; reject at usual levels.
		[RCL] 30	3.8504	Display value of $t_s$ .
	1	[b]	1.0000	Use $H_1$ -code of 1 making $H_0 : \mu_x - \mu_y \leq 2$ the disclaimer.
	2	[R/S]	0.0271	With $\theta_0 = 2$ , P-value is enough to reject at $\alpha = 5\%$ .
<p>(2) A test of color perception was administered to a control group (X) and an experimental group (Y) with results:</p> <p>x: 16.3 14.7 12.3 13.5 16.0 17.1 17.3</p> <p>y: 14.0 16.5 17.7 15.9 18.0 16.3</p> <p>Analyze the two groups for differences. Also test for equality of variances.</p> <p>Solution assuming <math>\sigma_x = \sigma_y</math>:</p>				
DE 0.		[J]	DATA?	Initialize ZS-6 for independent data entry.
1b.	16.3	[R/S]	1.000	Enter first x-value.
	14.7	[R/S]	2.0000	Continue x-values assuming data are independent.
	12.3	[R/S]	3.0000	
	13.5	[R/S]	4.0000	
	16.0	[R/S]	5.0000	
	17.1	[R/S]	6.0000	
	17.3	[R/S]	7.0000	Last x-value entered; $n_x = 7$ .
		[j]	0.0000	Prepare for y-values.
	14	[R/S]	1.0000	Begin entering y-value
	16.5	[R/S]	2.0000	(as with label B in ST-04)
	17.7	[R/S]	3.0000	
	15.9	[R/S]	4.0000	
	18	[R/S]	5.0000	
	16.3	[R/S]	6.0000	Conclude y-entries; $n_y = 6$
DE 2.		[d]	0.0000	Process data.
INA 2.	0	[c]	0.0000	Enter $H_1$ -code for two-sided test.
	0	[R/S]	0.2740	Display P-value (for $\theta_0 = 0$ ) of 0.27;
		[RCL] 30	-1.1512	Accept $H_0$ ( $t_s = -1.15$ ).
INA 3.		[C]	11.0000	Reveal d.f. = $n_x + n_y - 2 = 11$ for this case.
	2.201	[R/S]	-3.1615	Entering $t_{.025} = 2.201$ , CI runs from
		[X<>Y]	0.9900	$\lambda = -3.16$ to $u = 0.99$ which does include 0.



<u>ZS STEP</u>	<u>ENTER</u>	<u>PRESS</u>	<u>DISPLAY</u>	<u>COMMENTS</u>
<u>Solution assuming <math>\sigma_x \neq \sigma_y</math>:</u>				
INB 1.	Same as INA so data are already entered and processed.			
INB 2.		[A]	10.0000	Calculates degrees of freedom for
	2.228	[R/S]	-3.1404	approximate CI based on Welch t.
		[X<>Y]	.9690	Comes close to preceding solution.
INB 3.	0	[a]	0.0000	Begins Welch t-test with $H_1$ -code
	0	[R/S]	0.2663	followed by $\theta_0 = 0$ to yield about the same P-value.
<hr/>				
<u>To test for <math>\sigma_x^2 = \sigma_y^2</math>:</u>				
NV 1.	Same as INA			
NV 2.	0	[SF]04	0.0000	$H_1$ -code for two-sided test. Flag 4 signals NV a test is being called for.
		[D]	.5645	Large P-value; accept $\sigma_x^2 = \sigma_y^2$ with
		[RCL]30	1.7290	ts = 1.73.
NV 3a.				To take a CI point of view
		[D]	6.0000	Displays $v_1 = n_x - 1$ .
		[R/S]	5.0000	Displays $v_2 = n_y - 1$
NV 3b.	6.98	[STO]31	6.9800	Enter $F_{.025}$ with d.f. = (6,5).
NV 3c.	5.99	[STO]41	5.9900	Enter $F_{.025}$ with reversed d.f. = (
		[R/S]	0.2477	Shows a 95% CI that includes the
		[X<>Y]	10.3565	value 1. Accept $\sigma_x^2 = \sigma_y^2$ .

(3) A sample of 60 exponential times to failure averaged  $\bar{x} = 1306$  hrs.

Six independent times averaged  $\bar{y} = 1247$  hours. Test  $H_0 : \mu_x \leq \mu_y$ .

Solution:

Exp 1.	60	[STO]13	60.0000	Enter Summary Data
	6	[STO]06	6.0000	
	1306	[STO]47	1,306.0000	
	1247	[STO]37	1,247.0000	Data entry concluded.
Exp 2.	1	[SF]04	1.0000	Enter $H_1$ -code for $H_1 : \mu_x > \mu_y$ and set flag 4 to signal H-test.
		[E]	0.5043	P-value of 0.50 obtained; do not reject.
Exp 3a.		[E]	120.0000	$v_1 = 2n_x$ displayed.
		[R/S]	12.0000	$v_2 = 2n_y$ displayed.

<u>ZS STEP</u>	<u>ENTER</u>	<u>PRESS</u>	<u>DISPLAY</u>	<u>COMMENTS</u>
3b.	2.35	[STO]31	2.3500	F <sub>.05</sub> for $\nu_1 = 100$ , $\nu_2 = 10$ entered
	1	[STO]41	1.0000	1 store in $R_{41}$ to compute lower CI
		[R/S]	0.4457	Lower bound on $\mu_x/\mu_y$ displayed.

## Chapter 7 Proportions

This chapter represents the most successful transfer of programs of all. Indeed, the only remarks that need to be added to the existing programs is to remind you once more that all references to register  $R_{03}$  in TI are to be replaced with  $R_{06}$  in HP, that  $[X<>Y]$  is the HP version of  $[x\ t]$  (so that any reference to TI  $R_T$  should be replaced by  $R_Y$ ). Finally, since ZS-7 has been assigned to  $[J]$ , you should press the latter key whenever you need to access the programs here and is the only initialization necessary.

TEP	PROCEDURE	ENTER	PRESS	DISPLAY
(p)	<u>Bernoulli Parameter</u>			
0.	Initialization (if not already in ZS-7)		[J]	0.0000
1.	Data Entry			
	a. Enter Sample Size	n	[STO]06	n
	b. Enter Proportion Estimate	$\hat{p}$	[STO]40	$\hat{p}$
2.	<u>Test <math>H_0 : p = p_0</math></u>			
	a. Enter $H_1$ -code*	$H_1$ -code	[b]	$H_1$ -code
	b. Enter $p_0$ and Compute P-value OR:	$p_0$	[R/S]	P
	b'. For n Large (Normal Test)	$p_0$	[c]	P
3.	<u>CI for p for n large</u>			
	Enter Risk and Calculate Limits	$\alpha/2$	[C]	ℓ
	Note: For One-sided Limits, Enter $\alpha$ and Ignore ℓ or u.		[X<>Y]	u
4.	<u>CI for p for n small</u>			
	a. Find first d.f. for F.		[B]	$\nu_1$
			[R/S]	$\nu_2$
	b. Enter $F_{\alpha/2}$ with d.f. = ( $\nu_1, \nu_2$ )	$F_{\alpha/2}$	[STO]31	$F_{\alpha/2}$
	c. Find second d.f. for F		[R/S]	$\nu_1$
			[R/S]	$\nu_2$
	d. Enter $F_{\alpha/2}$ with new d.f.	$F_{\alpha/2}$	[STO]41	$F_{\alpha/2}$
	e. Calculate limits		[R/S]	ℓ
			[X<>Y]	u
	Note: For Lower One-sided Limit, enter $F_{\alpha}$ at Step 3b, 1 at Step 3d and Ignore u.			
	For Upper One-sided Limit, enter 1 at Step 3b, $F_{\alpha}$ at Step 3d and Ignore ℓ.			
$p_x - p_y$ )	<u>Two Bernoulli Parameters</u>			
1.	Data Entry			
	a. Enter Sample Sizes	$n_x$	[STO]13	$n_x$
		$n_y$	[STO]06	$n_y$
	b. Enter Proportion Estimates	$\hat{p}_x$	[STO]47	$\hat{p}_x$
		$\hat{p}_y$	[STO]37	$\hat{p}_y$

\*

$$H_1 \text{-code} = \begin{cases} 1 & \text{if } H_1 : \theta > \theta_0 \\ 0 & \text{if } H_1 : \theta = \theta_0 \\ -1 & \text{if } H_1 : \theta < \theta_0 \end{cases}$$

ZS-7		USER INSTRUCTIONS				2.	
STEP	PROCEDURE				ENTER	PRESS	DISPLAY
2.	<u>Test <math>H_0 : p_x = p_y</math></u> Enter $H_1$ -code and Calculate P-value				$H_1$ -code	[a]	P
3.	<u>CI for <math>p_x - p_y</math></u> Enter Risk and Calculate Limits				$\alpha/2$	[A] [X<>Y]	$\ell$ u
Note: For One-sided Limits Enter $\alpha$ and Ignore $\ell$ or u.							
<u>Register Contents</u>							
00	10	20	30	40	$\hat{\theta}$		
01	11	Used 21	31	$z_{\alpha/2}, F_{\alpha/2}$	41	$F_{\alpha/2}$	
02	12	Used 22	32	SE	42		
03	13	$n_x$ 23	Used 33	Used	43		
04	u 14	24	34	$\theta_0$	44		
05	$\ell$ 15	25	35		45		
06	$n(n_y)$ 16	26	36		46		
07	17	Used 27	37	$\hat{p}_y$	47	$\hat{p}_x$	
08	BIN $p(0)$ 18	Used 28	$H_1$ -code 38		48		
09	19	Used 29	$p(ts)$ 39	$e(\hat{\theta}+e)$	49		

#### Assignments

ZS-7 | J

#### Labels Used

01 A a  
02 B b  
03 C  
04  
05  
06

## ZS-7 EXAMPLES

- (1) In independent Bernoulli trials, there were exactly four successes. Find a 95% CI for  $p$  and test  $H_0 : p = 0.5$ .

Solution:

ZP STEP	ENTER	PRESS	DISPLAY	COMMENTS
B(p) 1.	9.	[STO]06	9.0000	Enter sample size.
	.44...	[STO]40	0.44...	Enter $\hat{p} = 4/9$ , the estimate of $p$ .
4a.		[B]	12.0000	Since $n$ is small find first pair
		[R/S]	8.0000	of d.f. = (10,10).
4b.	4.20	[STO]31	4.2000	Enter first $F_{.025}$ percentile.
4c.		[R/S]	10.0000	Discover revised d.f. = (12,8).
		[R/S]	10.0000	
4d.	3.72	[STO]41	3.72	Store second $F_{.025}$ percentile.
		[R/S]	0.1370	Lower confidence limit displayed
		[X<>Y]	0.7881	and $u$ found in $R_Y$ .
3.	0.	[b]	0.0000	Enter $H_1$ -code for $H_1 : p \neq 0.5$ .
	0.5	[R/S]	1.0000	Significance level 1; accept $H_0$ .

- (2) A device was tested 25 times and passed 23 times. Find a lower one-sided CI on  $p$ , the probability of passing. Test  $H_0 : p \geq 0.95$ .

Solution:

B(p) 1.	25	[STO]06	25.0000	Enter data as above.
	23÷25	[STO]40	0.9200	$\hat{p} = 23/25 = 0.92$
2a.	-1	[b]	-1.0000	Enter $H_1$ -code for $H_1 : p < 0.95$ .
2b.	0.95	[c]	0.2456	Comparing with large sample test.
4a.		[B]	6.0000	Initial d.f. for small $n$ CI (to
		[R/S]	46.0000	be ignored along with $v_2$ .
4b.	2.29	[STO]31	2.2900	Following instructions store 1 in
4c.		[R/S]	48.0000	$R_{31}$ . Calculate new d.f. $v_1 = 6$
		[R/S]	4.0000	and $v_2 = 46$ .
4d.	1	[STO]41	1.0000	Enter $F_{.05}$ for d.f. = (6,50) and
		[R/S]	0.7700	calculate lower confidence bound.

- (4) A sample of size 100 was taken from a lot with replacement and 2 defective items were found. Test the manufactures claim that  $p < 0.05$  at  $\alpha = .01$ .



<u>ZS STEP</u>	<u>ENTER</u>	<u>PRESS</u>	<u>DISPLAY</u>	<u>COMMENTS</u>
<u>Solution:</u>				
B(p) 1.	100.	[STO]06	100.0000	Enter data as usual.
	.02	[STO]40	0.0200	
2a.	-1.	[b]	-1.0000	$H_1$ -code for $H_1 : p < .05$ , the null hypothesis being $H_0 : p \geq .05$ , the disclaimer.
2b.	.05	[R/S]	0.1183	Enter $p_0$ and find $P = 0.12$ supporting $H_0$ not $H_1$ .
2b'.	.05	[c]	0.0843	Compare normal test.

(3) In a random sample of 500 men (X) 350 were found to favor a certain political issue. In a similar sample of 300 women (Y) 200 were so inclined. Is there any real difference between sexes on this issue?

Solution: To test  $H_0 : p_x = p_y$

B( $p_x - p_y$ ) 1a.	500	[STO]13	500.0000	Enter first sample size.
	300	[STO]06	300.0000	Enter second sample size.
1b.	0.7	[STO]47	0.7000	Enter first proportion estimate $\hat{p}_x$ .
	2/3	[STO]37	0.6667	Enter second proportion estimate $\hat{p}_y$ .
2.	0.	[a]	0.3248	Enter $H_1$ -code for $H_1 : p_x \neq p_y$
		[RCL]30	.9847	and find $P = 0.32$ with $ts = .98$ .
				Data supports $H_0$ .
3.	.025	[A]	-0.0335	A 95% CI for the difference $\mu_x - \mu_y$
		[X<>Y]	0.1001	extends from -.03 to + .10; include 0.

## Chapter 8 Analysis of Variance

The big change here is the data entry which is via STAT PAC through the Analysis of Variance routines provided there. Unfortunately, those routines are not complete enough to accomplish all of the goals set out in the text so that they too had to be supplemented with program ZS-8, whose user instructions follow.

### Section 8.2: One-Way Classifications

On page 95, you may replace the reference to ST-22 with execution of FCCDF in ZSTAT. If you will consult the user instructions, you will see that the program utilizes subroutine  $\Sigma$ AOVONE, assigned to [H] for convenience, in place of the TI program ST-06, referred to on page 197. After pressing [H] and seeing the display  $\Sigma$ AOVONE, you follow Steps 3-5 for inputting data (a model example is provided following the user instructions). A press of [E] while still in  $\Sigma$ AOVONE will then output most of the AOV table. The only, but important, missing item is the prob-value and that is calculated at Step 3 in ZS-8 by exiting  $\Sigma$ AOVONE with a press of [J] followed by [A]. The Scheffe' confidence intervals discussed in the very next section follow precisely the same user instructions as the TI and are duplicated in the HP User Instructions that follow.

### Section 8.4: Two-Way Classifications

In this section, the program  $\Sigma$ AOVTWO in STAT PAC is used for data entry in place of ST-06. This subroutine is assigned to [I] in ZS-8 and, once pressed, the instructions for data entry and output discussed on page 23 of the STAT PAC handbook should be followed. (Again, a model problem is provided at the end of the user instructions for ZS-8). This will provide for only part of the Two-Way table as displayed in this section of the text (and most other textbooks on the subject). To complete the table, you need to exit  $\Sigma$ AOVTWO by pressing [J] and then [C] will output the remaining items needed for the table including the all-important prob-values. Once again, the instructions for implementing the Scheffe' confidence interval formulas discussed in the next section are identical to those for the TI and are duplicated in the user instructions that follow.

STEP	PROCEDURE	ENTER	PRESS	DISPLAY
AOV-1	<u>One-Way Analysis of Variance</u>			
0.	INITIALIZATION (if not already in ZS-8)		[J]	xxxx
1.	Enter Data Using $\Sigma$ AOVONE NOTE: Record Each Row Mean		[H]	$\Sigma$ AOVONE
2.	Calculate AOV Table Entries NOTE: These Steps may NOT be repeated once Step 3 is executed.		[E] [R/S] [R/S] [R/S] [R/S] [R/S] [R/S] [R/S] [R/S]	SS RSS ESS K-1 N-K N-1 MRSS MESS F
3.	Exit $\Sigma$ OVONE and compute P-value	F	[J] [A]	F P
4.	Confidence Intervals for Contrasts (After Step 2)  a. Initialize  b. Enter Contrast Data (Repeat for each i; ignore any $c_i = 0$ )  c. Enter F-percentile d.f. = (K-1, N-K), and calculate CI	$c_i$ $\bar{x}_i$ $n_i$  $F_\alpha$	[e]  [R/S] [R/S] [R/S]  [a] [X<>Y]	0.0000  $c_i$ $\bar{x}_i$ i  l u
	NOTE 1: Steps 3abc may be repeated.			
	NOTE 2: These Steps are also valid if $R_{03}$ and $R_{48}$ are manually stored.			

## REGISTER CONTENTS

00	SS	10	Used	20		30	F	40	50	$\Sigma c_i \bar{x}_i$
01	RSS	11	N-K	21	FCDF	31	P	41	51	Last $c_i$
02	ESS	12	Used	22		32		42	52	Last $\bar{x}$
03	K-1	13		23		33		43	53	$\Sigma c_i^2 / n_i$
04	Used	14		24		34		44	54	Used
05	Used	15	R-1	25		35		45	55	
06	M	16	N-K	26		36		46	56	
07	Used	17	Used	27		37		47	57	
08	Used	18		28		38		48	MESS	58
09	K	19	for	29		39		49	e	59

ZS-8		USER INSTRUCTIONS		2.
STEP	PROCEDURE	ENTER	PRESS	DISPLAY
AOV-2	<u>Two-Way Analysis of Variance</u>			
0.	Initialize (if not in ZS-8)		[J]	x.xxxx
1.	Enter Data Using $\Sigma$ AOVTWO		[I]	$\Sigma$ AOVTWO
2.	<u>Calculate Row and Column Means</u> Calculate Row Means After each Row entry (Record). Repeat $i = 1, \dots, R$ .	C	[R/S] [÷]	$SUM_i$ $\bar{x}_{i.}$
	Calculate Column Means After each Column entry (Record). Repeat $j = 1, 2, \dots, C$ .	R	[R/S] [÷]	$\bar{x}_{.j}$
3.	Calculate AOV Table Entries NOTE: These Steps may NOT be repeated once Step 4 is executed		[E] [R/S] [R/S] [R/S] [R/S] [R/S] [R/S] [R/S] [R/S]	RSS CSS SS ESS R-1 C-1 $(R-1)(C-1)$ $F_R$ $F_C$
4.	Exit $\Sigma$ AOVTWO		[J]	$F_C$
5.	Complete the AOV output	$F_C$	[C] [R/S] [R/S] [R/S] [R/S]	MRSS MCSS MESS $P_R$ $P_C$

STEP	PROCEDURE	ENTER	PRESS	DISPLAY
6.	Confidence Intervals for Posterior Contrasts			
	a. Initialize		[E]	0.0000
	b. Enter Contrast Data	$c_i$	[R/S]	$c_i^2$
	(Repeat for each i (or j))	$\bar{x}_{i.}$ (or $\bar{x}_{.j}$ )	[R/S]	i (or j)
	c. CI for Row Contrast $\Sigma c_i \mu_{i.}$	$F_\alpha$	[D]	l
	d.f. = (R-1,(R-1)(C-1))		[X<>Y]	u
	d. CI for Column Contrast $\Sigma c_i \mu_{.j}$	$F_\alpha$	[d]	l
	d.f. = (C-1,(R-1)(C-1))		[X<>Y]	u
	NOTE 1: Steps 4abc or 4 abd may be repeated.			
	NOTE 2: These steps are also valid if the contents of registers $R_{48}, R_{58}, R_{59}$ below are stored manually.			

REGISTER CONTENTS:

00	Used	10	20	30	ts	40	50	$\Sigma c \bar{x}$
01	R	11	(R-1)(C-1)	21	31	41	51	last c
02	C	12	RSS	22	32	42	52	last $\bar{x}$
03	RC	13	CSS	23	33	43	53	$\Sigma c$
04	$x_{..}$	14	R-1	24	34	44	54	Used
05	$x_{..}^2$	15	C-1	25	35	45	55	
06	$\bar{x}_{..}$	16	(R-1)(C-1)	26	36	46	56	$F_R$
07	MESS	17	Used	27	37	47	57	$F_C$
08		18		28	38	48	MESS	R-1
09		19		29	39	49	e	C-1

Assignments

ZS-8	J
EAOVONE	H
EAOVTWO	I

Labels Used

01	A	a
02	C	d
03	D	e
	E	

EXAMPLES ZS-8

(1) Three types of solvents are tested on grease-soaked material and the amount of grease removed in milligrams is noted for several specimens with the following results:

Solvent A	11	12	12	
Solvent B	13	15		
Solvent C	12	10	11	11

Test the hypothesis of no differences in solvents.

Solution:

<u>ZP STEP</u>		<u>ENTER</u>	<u>PRESS</u>	<u>DISPLAY</u>	<u>COMMENTS</u>
			[J]	x.xxxx	
AOV-1, 1.			[H]	ΣAOVONE	Call for ΣAOVONE in the module.
ΣAOV	2.	11	[A]	1.00	Enter data for the first row.
		12	[A]	2.00	Enter data for the first row.
		12	[A]	3.00	Row 1 data entry concluded.
ΣAOV	5.		[R/S]	11.67	First row mean $\bar{x}_1$ calculated. Record!
			[R/S]	0.58	s for row 1 and row sum; ignore and
			[R/S]	35.00	go on to enter data for second row.
ΣAOV	2.	13	[A]	1.00	Running count begins anew.
		15	[A]	2.00	Row 2 data entry concluded.
ΣAOV	5.		[R/S]	14.00	Row mean $\bar{x}_2$ calculated. Record!
			[R/S]	1.41	Row 2 s and sum; ignore and proceed
			[R/S]	28.00	to enter data for third row.
ΣAOV	2.	12	[A]	1.00	
		10	[A]	2.00	
		11	[A]	3.00	
		11	[A]	4.00	Row 3 data entry concluded.
ΣAOV	5.		[R/S]	11.00	Value of $\bar{x}_3$ . (Record)
			[R/S]	0.82	Value of s and sum; ignore. Data
			[R/S]	44.00	entry concluded.
ΣAOV	6.		[E]	16.89	Value of SS displayed for total.
			[R/S]	12.22	Value of RSS
			[R/S]	4.67	ESS displayed
			[R/S]	2.00	d.f. for RSS
			[R/S]	6.00	d.f. for ESS displayed
			[R/S]	8.00	d.f. for SS displayed
			[R/S]	6.11	Value of MRSS
			[R/S]	0.78	Value of MESS



<u>ZS STEP</u>	<u>ENTER</u>	<u>PRESS</u>	<u>DISPLAY</u>	<u>COMMENTS</u>
		[R/S]	7.86	F-ratio = MRSS/MESS.
		[J]	7.8571	Exit $\Sigma$ AOVONE.
		[A]	0.0211	P-value of the F-ratio.

- (2) Find Scheffe 95% confidence intervals for the contrast  $\mu_1 - 0.5\mu_2 - 0.5\mu_3$  where MESS = 105.97 and  $K = 3$ ,  $N-k = 18$ ;  $\bar{x}_1 = 103.71$ ,  $\bar{x}_2 = 92$ ,  $\bar{x}_3 = 89$ ,  $n_1 = 7$ .

Solution:

AOV-1. 2.	2	[STO]14	2.0000	$v_1 = K-1 = 2$ stored in $R_{14}$
	105.97	[STO]48	105.9700	MESS stored in $R_{48}$ as required.
AOV-1. 3.		[e]	0.0000	Initialize CI routine.
	1	[R/S]	1.0000	First of triple triple $c_1, \bar{x}_1, n_1$ , entered.
	103.71	[R/S]	103.7100	Second member of triple
	7	[R/S]	1.0000	Sample size $n_1$ ; count of 1 (triple) displayed.
	-0.5	[R/S]	-0.5000	Beginning entry of $c_2, \bar{x}_2, n_2$ .
	92	[R/S]	92.0000	
	7	[R/S]	2.0000	Running count of 2 displayed.
	-0.5	[R/S]	-0.5000	Entering final triple
	89	[R/S]	89.0000	
	7	[R/S]	3.0000	Entry completed.
	3.49	[a]	0.6203	$F_{.05}$ for d.f. = (2,20) entered
		[X<>Y]	25.7997	and confidence limits displayed.
				Conclude contrast significantly different from 0.

- (3) Five teachers were matched with three schools to produce the following average scores on a standardized examination after a unit of instructions

Teachers Schools	A	B	C	D	E	$\bar{x}_{i.}$
I	53	47	46	50	49	49
II	61	55	52	58	54	56
III	51	51	49	54	50	51
$\bar{x}_{.j}$	55	51	49	54	51	

<u>ZS STEP</u>	<u>ENTER</u>	<u>PRESS</u>	<u>DISPLAY</u>	<u>COMMENTS</u>
Construct a two-way AOV table and find CI's for $\mu_1 - \mu_2$ and $\mu_1 - \mu_3$ .				
<u>Solution:</u>				
		[J]	x.xxxxx	
AOV-2 1.		[I]	ΣAOVTWO	Call for ΣAOVTWO from the module.
ΣAOV 3.	53	[A]	1.00	Enter first data value from row 1.
	47	[A]	2.00	Continue entering data from row 1.
	46	[A]	3.00	.
	50	[A]	4.00	.
	49	[A]	5.00	*until all the data from row 1 are entered
		[R/S]	245.00	
ΣAOV 5.	5	[÷]	49.00	Calculate and record row mean $\bar{x}_1$ .
ΣAOV 3.	61	[A]	1.00	Go on with first value from row 2
	55	[A]	2.00	and continue
	52	[A]	3.00	until all of
	58	[A]	4.00	the data from row 2
	54	[A]	5.00	have been entered.
ΣAOV 5.		[R/S]	280.00	Calculate and
	5	[÷]	56.00	record $\bar{x}_2$ .
ΣAOV 3.	51	[A]	1.00	Continue non-stop with data
	51	[A]	2.00	entry from the third and
	49	[A]	3.00	last row
	54	[A]	4.00	
	50	[A]	5.00	
ΣAOV 5.		[R/S]	255.00	Calculate and
	5	[÷]	51.00	record $\bar{x}_3$ .
ΣAOV 6.		[R/S]	COLUMN-WISE	Prepare for column computations.
ΣAOV 8.	53	[A]	1.00	Enter first value from column 1.
	61	[A]	2.00	Enter second value from column 1.
	51	[A]	3.00	Enter last value from column 1.
ΣAOV 10.		[R/S]	165.00	Calculate $\bar{x}_{.1}$ .
		[÷]	55.00	and record.
ΣAOV 8.	47	[A]	1.00	Repeat for column 2
	55	[A]	2.00	
	51	[A]	3.00	
ΣAOV 10.		[R/S]	153.00	Calculate and
	3	[÷]	51.00	record $\bar{x}_{.2}$

<u>ZS STEP</u>	<u>ENTER</u>	<u>PRESS</u>	<u>DISPLAY</u>	<u>COMMENTS</u>
$\Sigma$ AOV 8.	46	[A]	46.00	Repeat for column 3
	52	[A]	52.00	
	49	[A]	49.00	
$\Sigma$ AOV 10.		[R/S]	147.00	Calculate and
	3	[÷]	49.00	record $\bar{x}_{.3}$
$\Sigma$ AOV 8.	50	[A]	50.00	Repeat for column 4
	58	[A]	58.00	
	54	[A]	54.00	
$\Sigma$ AOV 10.		[R/S]	162.00	Calculate and
	3	[÷]	54.00	record $\bar{x}_{.4}$
$\Sigma$ AOV 8.	49	[A]	49.00	Repeat for column 5.
	54	[A]	54.00	
	50	[A]	50.00	
$\Sigma$ AOV 10.		[R/S]	153.00	Calculate and
	3	[÷]	51.00	record $\bar{x}_{.5}$
$\Sigma$ AOV 11.		[E]	130.00	Data compiled and RSS displayed
		[R/S]	72.00	CSS displayed.
		[R/S]	224.00	SS total sum of squares.
		[R/S]	22.00	ESS displayed
		[R/S]	2.00	Row d.f. = R-1 = 2 displayed.
		[R/S]	4.00	Column d.f. = C-1 = 4 displayed
		[R/S]	8.00	Error d.f. = (R-1)(C-1) displayed
		[R/S]	23.64	$F_R$ displayed
		[R/S]	6.55	$F_C$ displayed
		[J]	6.5455	Exit $\Sigma$ AOVTWO and enter ZS-8
ZS-7 5.		[C]	65.0000	MRSS displayed
		[R/S]	18.0000	MCSS displayed
		[R/S]	2.7500	MESS displayed
		[R/S]	0.0004	P-value for $F_R$ computed and displayed
		[R/S]	0.0122	P-value for $F_C$
	4.	[E]	0.0000	Initialize for Scheffe CI's
	1	[R/S]	1.0000	Enter $c_1 = 1$ to find CI for $\mu_{1.} - \mu_{2.}$
	49	[R/S]	1.0000	Enter row mean $\bar{x}_{1.}$
	-1	[R/S]	1.0000	Enter $c_2 = -1$ for contrast $\mu_{1.} - \mu_{2.}$

<u>ZS STEP</u>	<u>ENTER</u>	<u>PRESS</u>	<u>DISPLAY</u>	<u>COMMENTS</u>
	56	[R/S]	2.0000	All non-zero c's now entered.
	4.46	[D]	-10.1324	$F_{.05} = 4.46$ for d.f. = (2,8)
		[X<>Y]	-3.8676	$\ell$ is displayed followed by u.
		[RCL]49	3.1324	The value of e retrieved from $R_{49}$ for further comparisons.
		[E]	0.0000	Re-initialize C.I. program.
	1	[R/S]	1.0000	Enter $c_1$ for contrast $\mu_{.1} - \mu_{.3}$ .
	55	[R/S]	1.0000	$\bar{x}_{.1}$ , the first column mean is entered.
	-1	[R/S]	1.0000	Enter $c_2 = -1$
	49	[R/S]	2.0000	Enter third column mean $\bar{x}_{.3}$ .
	3.84	[d]	0.6934	Enter $F_{.05}$ for d.f. = (4,8) and calculate Lower limit.
		[X<>Y]	11.3066	Upper limit retrieved from $R_Y$ .
		[RCL]49	5.3066	Value of e found in $R_{49}$ for further comparisons.

## Chapter 9 Simple Linear Regression

It is rather surprising that the HP is not hard-wired for at least simple linear regression as is the TI and many lesser hand-held calculators. There is a routine in STAT PAC, but, just as with the TI statistics module, no provision is made for confidence intervals, tests of hypotheses, etc.. In order to make the HP output match the discussions given in the text, we have created a simple data entry scheme in a program called ZS-9 (assigned the label [I] for convenient access). Once that program is accessed, you have only to press [D] (for data) and enter the successive pairs of numbers as per Step 2 of the instructions. At the conclusion of entry, press [e] to compile the data whereupon the degrees of freedom will be displayed for you. At this point, you may enter a t-percentile if you like. In any event, the effect of entering data this way will force the register contents to almost agree with those of the TI entry, with a couple of notable exceptions. Referring to page 237, HP  $R_{06}$  as usual must replace TI  $R_{03}$  and then the TI  $R_{04}$ ,  $R_{05}$ ,  $R_{06}$  become HP  $R_{03}$ ,  $R_{04}$ ,  $R_{05}$ , respectively. As usual, the HP functions MEAN and SDEV replace TI  $[\bar{x}]$  and  $[\text{INV}][\bar{x}]$  and will output the same quantities. There is a subroutine within ZS-9 called [Op]11 whose execution will exactly match that of TI [Op]11 as referred to in this chapter. Try this on the data in Example 9.1 to verify the results published on page 238. Similarly, there are subroutines in ZS-9 called [Op]14 and [Op]15 that will function in exactly the same way as their TI counterparts referred to in the text. In Note 2 on page 238, HP will display the message DATA ERROR if the data all have the same carrier value. Similarly, in Note 1 on page 250, HP will display the message ALL REALS to signify that the CI does not exist. Otherwise, all of the instructions for the various regression routines through Section 9.4 are identical to those given in the book for the TI. For that reason only Step 1 needs to be modified and that has been taken care of in the User Instructions that follow on the next page.

### Section 9.5: Curve Fitting

The procedures in this section utilize the TI statistics module and, fortunately, most of them are duplicated in the HP STAT PAC under the same title, Curve Fitting, beginning on page 32 of the STAT PAC handbook. The only problem is that the HP notation differs slightly from that of TI. Thus, TI  $b$  is HP  $a$  and TI  $m$  is HP  $b$ . You will have to make that adjustment in order to use your HP for solving problems in this section. The output of label [E] in that program, however, will produce the right estimated equations and can be used to verify the numbers given in Example 9.9 as well as most of the exercises. The one big departure is that HP makes no allowance for creating your own user defined transformation so that examples like 9.10 on page 265 cannot be checked. Those are not too common, however, so that for the main type of transformations you are likely to run into in practice, what is provided by STAT PAC will suffice. All of the answers to the problems, with the exception of 40e, can be verified with those routines.

STEP	PROCEDURE	ENTER	PRESS	DISPLAY
I 0.	<u>Initialization</u> (if not already in ZS-9)		[I]	0.0000
1.	Clear registers		[D]	0.0000
2.	Enter data (repeat $i = 1, 2, \dots, n$ )	$x_i$ $y_i$	[ENTER] [R/S]	$x_i$ $i$
3.	Compile data		[e]	$n-2$
4.	Enter percentile for CI's (d.f. = $n-2$ ) (may also store manually in $R_{31}$ at any time)	$t_{\alpha/2}$	[R/S]	$t_{\alpha/2}$
SLOPE				
1	CI for $m$		[A] [X<>Y]	$l$ $u$
2	Test $H_0: m = m_0$ . a. Enter $H_1$ -code.* b. Enter hypothesized value.	$H_1$ -code $m_0$	[a] [R/S]	$H_1$ -code $P$
INT				
1	CI for $b$		[B] [X<>Y]	$l$ $u$
2	Test $H_0: b = b_0$ . a. Enter $H_1$ -code. b. Enter hypothesized value.	$H_1$ -code $b_0$	[b] [R/S]	$H_1$ -code $P$
at $x_0$	CI for $mx_0 + b$	$x_0$	[C] [X<>Y]	$l$ $u$
at $x_0$	PI for $Y_0 = mx_0 + b + e$	$x_0$	[c] [X<>Y]	$l$ $u$
DISC	CI for $x^*$ , when $y^*$ is observed	$y^*$	[d] [X<>Y]	$l$ $u$
CORR	Test $H_0: \rho = 0$ . Enter $H_1$ -code. Note: Valid whenever $n-2 \in R_{15}$ and $r \in R_{44}$	$H_1$ -code	[E]	$P$

\*Note:  $H_1$ -code  $\begin{cases} -1 & \text{for } H_1: \theta < \theta_0 \\ 0 & \text{for } H_1: \theta \neq \theta_0 \\ 1 & \text{for } H_1: \theta > \theta_0 \end{cases}$



# REGISTER CONTENTS:

00	Used	10	20	30	ts	40	$\hat{\theta}$		
01	$\Sigma y_i$	11	21	31	$t_{\alpha/2}$	41	Used		
02	$\Sigma y_i^2$	12	22	Used	32	42	d		
03	$\Sigma x_i$	13	23	by	33	s	43	$y^*-\bar{y}$	
04	$\Sigma x_i^2$	14	n-1	24	TCDF	34	$\theta_0$	44	r
05	$\Sigma x_i y_i$	15	v = n-2	25		35	$\hat{s}_m$	45	$\hat{m}$
06	n	16	26		36	$\hat{s}_B$	46	$\hat{b}$	
07	$\Sigma (y_i - \bar{y})^2$	17	27		37	$\hat{s}_Y$	47	$\bar{x}$	
08	$\Sigma (x_i - \bar{x})^2$	18	28	$H_1$ -code	38	$\hat{s}_{Mx_0+\hat{B}}$	48	$\bar{y}$	
09		19	29	P(ts)	39	$e(\hat{\theta} \pm e)$	49		

For curve fitting, consult STAT PAC p. 32.

## Assignments

ZS-9	I
OP12	H
OP13	P
OP14	h
OP15	i

## Labels Used

01	A	a
02	B	b
03	C	c
04	D	d
05	E	e

The resistance of a length of wire is thought to be a linear function of the temperature of the wire. For a given temperature, errors in readings of resistance are normally distributed with mean 0 and variance  $\sigma^2$ . The following readings were made at the temperatures indicated.

Temperature	0	10	20	30	40	50
Resistance	22.6	25.1	29.0	29.9	33.4	34.8

- Estimate the regression of resistance on temperature.
- Estimate the resistance if temperature is 25.
- Estimate the temperature if resistance is 30.
- Find a 95% confidence interval for the slope,  $m$ .
- Find a 95% confidence interval for the intercept  $b$ .
- Find a 95% confidence interval for the expected resistance when temperature is 25.
- Find a 95% prediction interval for the measured response when temperature is 25.
- Find a 95% discrimination interval for the temperature at which a resistance of 30 is observed.
- Test the hypotheses  $H_0: m = 0$  vs.  $H_1: m \neq 0$ .
- Test the hypotheses  $H_0: b \leq 20$  vs.  $H_1: b > 20$ .
- Calculate the coefficient of determination.
- Test  $H_0: \rho = 0$  vs.  $H_1: \rho \neq 0$ .

# SOLUTIONS:

ZS STEP	ENTER	PRESS	DISPLAY	COMMENTS
I 0.		[I]	x.xxxx	
1.		[D]	0.0000	Clear data registers
I 2.	0	[ENTER]	0.0000	Enter $x_1$ .
	22.6	[R/S]	1.0000	Enter $y_1$ , update data base; (x,y) count displayed.
	10	[ENTER]	10.0000	Enter $x_2$ .
	25.1	[R/S]	2.0000	Enter $y_2$ , update data base
	20	[ENTER]	20.0000	Enter $x_3$ .
	29	[R/S]	3.0000	(x,y) - count displayed.
	30	[ENTER]	30.0000	
	29.9	[R/S]	4.0000	(x,y) - count displayed.
	40	[ENTER]	40.0000	
	33.4	[R/S]	5.0000	(x,y) - count displayed.
	50	[ENTER]	50.0000	
	34.8	[R/S]	6.0000	Value of $n = 6$ concludes data entry.

ZS STEP	ENTER	PRESS	DISPLAY	COMMENTS
I 3.		[e]	4.0000	Compile data; display d.f. = 4.
I 4.	2.776	[R/S]	2.7760	Enter $t_{.025}$ for d.f. = 4.
		[H]	22.9333	$\hat{b}$
		[X<>Y]	0.2480	$\hat{m}$ ; $\hat{y} = .248x + 22.93$ answers (a).
	25	[h]	29.1333	$\hat{y}$ for $x = 25$ answers (b).
	30	[i]	28.4946	$x$ for $y = 30$ answers (c).
SLOPE 1.		[A]	0.1983	$\ell$
		[X<>Y]	.2977	u, so CI is $.198 < m < .298$ , answering (d).
INT 1.		[B]	21.4294	$\ell$
		[X<>Y]	24.4373	u, so CI is $21.4 < b < 24.4$ , answering (e).
$\mu$ at $x_0$	25	[C]	28.2850	$\ell$
		[X<>Y]	29.9817	u, so CI is $28.28 < 25m + b < 29.9$ answering (f).
$Y$ at $x_0$	25	[c]	26.8889	$\ell$
		[X<>Y]	31.3778	u, so PI is $26.89 < Y_0 < 31.38$ , answering (g)
DISC	30	[d]	19.3744	$\ell$
		[X<>Y]	37.9069	u, so CI is $19.37 < x^* < 37.91$ , answering (h).
SLOPE 2a.	0	[a]	0.0000	Enter $H_1$ -code for $H_1: m \neq 0$
2b.	0	[R/S]	0.0002	Significance of test; reject $H_0$ ; answers (i).
INT 2a.	1	[b]	1.000	Enter $H_1$ -code for $H_1: b > 20$
2b.	20	[R/S]	0.0028	Significance of test; reject $H_0$ ; answers (j).
		[P]	0.9897	Calculates and displays $r$
		[ $x^2$ ]	0.9796	$r^2 = 0.98$ is the answer to (k).
CORR	0	[U][E][U]	0.0002	Significance of test of $H_0: \rho = 0$ (must agree with (i)).

---

[U] = [USER]

Chapter 10 Multiple Regression

Only the data entry scheme differs from the TI version of this program. The regression program  $\Sigma$ MLRXY in STAT PAC is utilized for entering the data in the HP version and partial processing takes place in that program. Further processing takes place in program ZS-10 (assigned to label [J] for easy entry from STAT PAC) so that even the register contents (with the slight modification given below) and the remaining instructions will match those given in the book.

Once ZS-10 is entered, a press of [d] will force the pointer to STAT PAC program  $\Sigma$ MLRXY. Data are then entered as follows: first, x and y are successively entered with the [ENTER] key and then the value of z with [A]. At the conclusion of data entry, pressing [E] will cause partial processing, ending with a display of the coefficient of determination. It is at this point that STAT PAC must be exited and ZS-10 entered with a press of [J]. Then, pressing [e] will cause the rest of the processing to take place. Thereafter, the user instructions for ZS-10 may be followed to the letter. For that reason, only the DE instructions need to be modified and are summarized below. The usual sample problem is presented starting on the following page.

SIZE 050

STEP	PROCEDURE	ENTER	PRESS	DISPLAY																																																							
DE	Data Entry																																																										
0	Initialization		[J] [d]	0.0000 $\Sigma$ MLRXY																																																							
1	ENTER DATA (repeat i=1,...,n)	xi yi zi	[ENTER] [ENTER] [A]	xi yi i																																																							
2	Compile Data (partial) Complete compile		[E] [J] [e]	$R^2$ 0.0000 n-3																																																							
3	Enter t-percentile (d.f. = n-3)	$t_{\alpha/2}$	[R/S]	$t_{\alpha/2}$																																																							
<table><tr><th colspan="2">Assignments</th><th colspan="2">Labels Used</th><th>Register Contents</th></tr><tr><td>ZS-10</td><td>J</td><td>01</td><td>A a</td><td>40</td></tr><tr><td><math>\Sigma</math>MLRXY</td><td>e</td><td>02</td><td>B b</td><td>41</td></tr><tr><td></td><td></td><td></td><td>C c</td><td>42</td></tr><tr><td></td><td></td><td></td><td>D d</td><td>43</td></tr><tr><td></td><td></td><td></td><td>E e</td><td>44</td></tr><tr><td></td><td></td><td></td><td></td><td>45</td></tr><tr><td></td><td></td><td></td><td></td><td>46 <math>\hat{a}_0</math></td></tr><tr><td></td><td></td><td></td><td></td><td>47 <math>a_1</math></td></tr><tr><td></td><td></td><td></td><td></td><td>48 <math>a_2</math></td></tr><tr><td></td><td></td><td></td><td></td><td>49</td></tr></table>					Assignments		Labels Used		Register Contents	ZS-10	J	01	A a	40	$\Sigma$ MLRXY	e	02	B b	41				C c	42				D d	43				E e	44					45					46 $\hat{a}_0$					47 $a_1$					48 $a_2$					49
Assignments		Labels Used		Register Contents																																																							
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				48 $a_2$																																																							
				49																																																							

# ZS-10 EXAMPLE.

The data below represent characteristics of a sample of automobiles.

Weight	3810	4220	2900	3290	3400	3920	4350
Horsepower	255	180	16	120	100	140	150
Cost	7999	9221	8222	9010	10099	11019	11219

- Regress cost on weight and horsepower.
- Predict the cost of an automobile weighting 5,000 lbs. and having 160 horsepower.
- Determine the significance of horsepower for predicting cost.
- Find a 95% confidence interval for the coefficient of weight.
- Estimate  $\sigma$ .
- Find the coefficient of determination.

## Solution:

<u>ZS STEP</u>	<u>ENTER</u>	<u>PRESS</u>	<u>DISPLAY</u>	<u>COMMENTS</u>
DE 0.		[J]	0.0000	Enter program ZS-10
1.		[d]	EMLRXY	Initialize EMLRXY for data entry.
	3810	[ENTER]	3810.00	Enter $x_1$ .
	255	[ENTER]	255.00	Enter $y_1$ .
	7999	[A]	1.00	Enter $z_1$ completing one triplet.
	4220	[ENTER]	4220.00	Enter $x_2$ .
	180	[ENTER]	180.00	Enter $y_2$ .
	9221	[A]	2.00	Enter $z_2$ completing two triplets.
	2900	[ENTER]	2900.00	Enter $x_3$ .
	96	[ENTER]	96.00	Enter $y_3$ .
	8222	[A]	3.00	Enter $z_3$ completing three triplets.
	3290	[ENTER]	3290.00	Enter $x_4$ .
	120	[ENTER]	120.00	Enter $y_4$ .
	9010	[A]	4.00	Enter $z_4$ , completing four triplets.
	3400	[ENTER]	3400.00	Enter $x_5$ .
	100	[ENTER]	100.00	Enter $y_5$ .
	10099	[A]	5.00	Enter $z_5$ , completing five triplets.
	3920	[ENTER]	3920.00	Enter $x_6$ .
	140	[ENTER]	140.00	Enter $y_6$ .
	11019	[A]	6.00	Enter $z_6$ , completing six triplets.
	4350	[ENTER]	4350.00	Enter $x_7$ .
	150	[ENTER]	150.00	Enter $y_7$ .
	11219	[A]	7.00	Enter $z_7$ , completing last triplet.

<u>ZS STEP</u>	<u>ENTER</u>	<u>PRESS</u>	<u>DISPLAY</u>	<u>COMMENTS</u>
		[E]	0.80	Process data and display $R^2$ .
		[J]	0.8050	Exit $\Sigma$ MLRXY and enter ZS-10
I 2.		[e]	4.0000	Process trivariate data further and display $v = 4$ .
I 3.	2.776	[R/S]	2.7760	Enter $t_{.025}$ for CI's.
D		[D]	3361.7167	Display $\hat{a}_0$ .
		[R/S]	2.4657	Display $\hat{a}_1$ .
		[R/S]	-19.7686	Recall and display $\hat{a}_2$ .
	Regression equation: $\hat{z} = 3361.72 + 2.466x - 19.769y$			.
E	5000	[E]	0.0000	Prepare to predict Z.
	160	[R/S]	12,527.0724	Predicted cost.
C	0	[c]	0.0000	Testing $H_0 : a_2 = 0$ vs. $H_1 : a_2 \neq 0$ .
	0	[R/S]	0.0318	Significance level for $a_2$ ( $t_s = -3.2$ ).
B		[B]	0.6786	Lower 95% limit for $a_1$ .
		[X<>Y]	4.2527	Upper 95% limit for $a_1$ .
		[RCL]33	691.7057	$\hat{\sigma} = s$ .
		[RCL]27	0.8050	Recall and display $R^2 = .80$ .



## APPENDIX

In the appendix that follows, you will find a complete listing of the programs discussed in the previous sets of User Instructions. These programs are named according to their ZP or ZS application by chapter and, occasionally, by section. To implement the programs, the first step is to key in each step into your calculator exactly as it appears in the listing. (Consult the Owner's Handbook for any instructions that may be unfamiliar.) Next, you should assign various subroutines using the function ASN according to the assignments listed just after the register contents in the User Instructions for each program. Then place your HP41-C in USER mode and record the program on a magnetic card for future reference.

01•LEL *ZP2*	51•LEL d	99 1
02 SREG 01	52 STO 00	100 STO 14
03 CLZ	53 1/X	101 RCL 12
04 20	54 STO 13	102 0
05 STO 07		103 X=Y?
06 21	55•LEL 03	104 GTO 10
07 STO 03	56 RCL IND 07	105 RTN
08 0	57 RCL 13	
09 RTN	58 XEQ 02	106•LEL b
	59 DSE 00	107 XEQ 08
10•LEL A	60 GTO 03	
11 STO IND 07	61 RTN	108•LEL 09
12 RCL 06		109 RCL 11
13 1	62•LEL E	110 ST* 14
14 +	63 1/X	111 1
15 STOP	64 STO 13	112 ST- 11
16 STO IND 03		113 DSE 12
17 RDN	65•LEL 04	114 GTO 09
18 X<>Y	66 STOP	
19 R↑	67 STO IND 07	115•LEL 10
	68 RCL 13	116 RCL 14
20•LEL 02	69 XEQ 22	117 STOP
21 STO IND 03	70 GTO 04	
22 Σ+		118•LEL c
23 2	71•LEL C	119 XEQ 08
24 ST+ 07	72 1	120 X>Y?
25 ST+ 03	73 STO 03	121 GTO 12
26 RCL 06	74 -	122 RDN
27 RTN	75 STO 00	123 RCL 11
	76 365	124 X<>Y
28•LEL B	77 STO 01	125 X>Y?
29 2	78 STO 02	126 GTO 12
30 *		
31 18	79•LEL 05	127•LEL 11
32 +	80 1	128 RCL 11
33 STO 09	81 ST- 01	129 ST* 14
34 1	82 RCL 01	130 1
35 +	83 RCL 02	131 ST- 11
36 STO 10	84 /	132 RCL 12
37 RCL IND 09	85 ST* 03	133 ST/ 14
38 RCL IND 10	86 DSE 00	134 DSE 12
39 *	87 GTO 05	135 GTO 11
40 RCL 05	88 1	136 GTO 10
41 /	89 RCL 03	
42 RTN	90 -	137•LEL 12
	91 RTN	138 0
43•LEL a		139 STOP
44 RCL 05	92•LEL 03	140 END
45 RTN	93 "H=?"	
	94 PROMPT	
46•LEL D	95 STO 11	
47 RCL IND 07	96 "R=?"	
48 STOP	97 PROMPT	
49 STO IND 08	98 STO 12	
50 GTO 02		

01+LBL \*2P3-2\*

02 CLRG  
03 20  
04 STO 01  
05 21  
06 STO 02  
07 0  
08 RTN

09+LBL A  
10 STO IND 01  
11 STOP  
12 STO IND 02  
13 1  
14 ST+ 03  
15 2  
16 ST+ 01  
17 ST+ 02  
18 RCL 03  
19 RTN

20+LBL 01  
21 RCL 03  
22 STO 00  
23 0  
24 STO 06  
25 STO 07  
26 20  
27 STO 01  
28 21  
29 STO 02  
30 RTN

31+LBL 02  
32 RCL IND 01  
33 STO 09  
34 XEQ B

35+LBL 05  
36 STO 04  
37 X12  
38 STO 05  
39 RCL IND 02  
40 ST+ 04  
41 ST+ 05  
42 RCL 04  
43 ST+ 06  
44 RCL 05  
45 ST+ 07  
46 2  
47 ST+ 01  
48 ST+ 02  
49 RTN

50+LBL E  
51 XEQ 01

52+LBL 03  
53 RCL IND 01  
54 XEQ 05  
55 DSE 00  
56 GTO 03

57+LBL 06  
58 RCL 07  
59 RCL 06  
60 X12  
61 -  
62 STO 03  
63 RCL 06  
64 RTN

65+LBL D  
66 XEQ 01

67+LBL 04  
68 XEQ 02  
69 DSE 09  
70 GTO 04  
71 GTO 06

72+LBL C  
73 STO 00  
74 0  
75 STO 10  
76 21  
77 STO 02

78+LBL 07  
79 RCL IND 02  
80 ST+ 10  
81 2  
82 ST+ 02  
83 DSE 00  
84 GTO 07  
85 RCL 10  
86 RTN

87+LBL B  
88 END

01*LBL *ZF3-3-	52 STO 16	105 RCL 20	157*LBL 18	203 RCL 13	254*LBL b
02 CF 02	53 RCL 14	106 *	158 1	204 STO 11	255 XEQ B
03 0	54 STO 01	107 1/X	159 STO 04	205 STO 12	256 1
04 STOP	55 RCL 13	108 ENTER↑	160 RCL 02	206 RCL 15	257 -
	56 STO 02	109 RCL 13	161 0	207 RCL 14	259 CHS
05*LBL A	57 XEQ *PMTCH-	110 ENTER↑	162 X=Y?	208 /	259 RTH
06 STO 00	58 ST/ 16	111 RCL 20	163 GTO 10	209 STO 22	
07 FS? 02	59 SF 02	112 -	164 RTH	210 ST* 11	
08 GTO 02		113 1		211 ST* 12	260*LBL E
09 RCL 14	60*LBL 02	114 +	165*LBL *PMTCH-	212 1	261 RCL 12
10 STO 24	61 0	115 *	166 XEQ 18	213 -	262 RCL 11
11 1/X	62 STO 20	116 ENTER↑		214 CHS	263 RTH
12 STO 22	63 RCL 16	117 RCL 15	167*LBL 19	215 STO 21	264 END
13 RCL 15	64 STO 06	118 ENTER↑	168 RCL 01	216 ST* 12	
14 ST- 24	65 STO 07	119 RCL 20	169 ST* 04	217 RCL 13	
15 ST* 22	66 0	120 -	170 1	218 Y↑X	
16 RCL 22	67 ENTER↑	121 1	171 ST- 01	219 STO 16	
17 STO 11	68 RCL 00	122 +	172 DSE 02	220 STO 06	
18 STO 12	69 X=Y?	123 *	173 GTO 19	221 STO 07	
19 1	70 GTO 05			222 SF 02	
20 -		124*LBL 04	174*LBL 10		
21 CHS	71*LBL 03	125 ST* 06	175 RCL 04	223*LBL 07	
22 STO 21	72 1	126 RCL 06	176 RTH	224 0	
23 ST* 12	73 ST+ 20	127 ST+ 07		225 STO 20	
24 RCL 13	74 RCL 20	128 DSE 00	177*LBL *CMBON-	226 RCL 16	
25 STO 03	75 ENTER↑	129 GTO 03	178 XEQ 18	227 STO 05	
26 ST* 11	76 RCL 15		179 X>Y?	228 STO 07	
27 ST* 12	77 -	130*LBL 05	180 GTO 12	229 RCL 00	
28 ENTER↑	78 1	131 RCL 06	181 RDH	230 0	
29 RCL 14	79 -	132 RCL 07	182 RCL 01	231 X=Y?	
30 -	80 CHS	133 RTH	183 X<>Y	232 GTO 05	
31 CHS	81 ENTER↑		184 X>Y?		
32 RCL 14	82 0	134*LBL 06	185 GTO 12	233*LBL 00	
33 1	83 X<>Y	135 1		234 1	
34 -	84 X<=Y?	136 STO 06	186*LBL 11	235 ST+ 20	
35 /	85 GTO 04	137 RCL 15	187 RCL 01	236 RCL 20	
36 ST* 12	86 CHS	138 STO 01	188 ST* 04	237 RCL 13	
	87 2	139 RCL 20	189 1	238 -	
37*LBL 01	88 +	140 STO 02	190 ST- 01	239 CHS	
38 RCL 24	89 RCL 14	141 XEQ *CMBON-	191 RCL 02	240 1	
39 RCL 13	90 +	142 STO 23	192 ST/ 04	241 +	
40 X<=Y?	91 RCL 13	143 RCL 14	193 DSE 02	242 RCL 20	
41 GTO 03	92 -	144 STO 01	194 GTO 11	243 /	
42 0	93 ENTER↑	145 RCL 13	195 GTO 10	244 RCL 22	
43 STO 16	94 0	146 STO 02		245 *	
44 SF 02	95 X<>Y	147 XEQ *CMBON-	196*LBL 12	246 RCL 21	
45 GTO 02	96 X<=Y?	148 ST/ 23	197 0	247 /	
	97 GTO 04	149 RCL 23	198 STOP	248 ST* 06	
46*LBL 09	98 1	150 GTO 04		249 RCL 06	
47 RCL 24	99 -		199*LBL 9	250 ST+ 07	
48 STO 01	100 ENTER↑	151*LBL a	200 STO 00	251 DSE 00	
49 RCL 13	101 0	152 XEQ A	201 FS? 02	252 GTO 00	
50 STO 02	102 X=Y?	153 1	202 GTO 07	253 GTO 05	
51 XEQ *PMTCH-	103 GTO 06	154 -			
	104 X<>Y	155 CHS			
		156 RTH			

01*LBL *ZP3-4*	52 CHS	103 -	153*LBL c	205 RCL 20
02 CF 01	53 RCL 13	104 CHS	154 XEQ C	206 /
03 CF 02	54 +	105 RTN	155 ENTER†	207 RCL 21
04 CF 03	55 1		156 1	208 *
05 CF 04	56 +	106*LBL E	157 -	209 ST* 06
06 0	57 RCL 20	107 RCL 12	158 CHS	210 RCL 06
07 STOP	58 /	108 RCL 11	159 RTN	211 ST+ 07
	59 RCL 22	109 RTN		212 DSE 00
	60 *		160*LBL A	213 GTO 19
08*LBL 0	61 RCL 21	110*LBL C	161 STO 00	214 GTO 05
09 STO 00	62 /	111 STO 00	162 FS? 04	
10 FS? 02	63 ST* 06	112 FS? 03	163 GTO 15	215*LBL 15
11 GTO 07	64 RCL 06	113 GTO 13	164 FS? 01	216 RCL 21
12 FS? 04	65 ST+ 07	114 FS? 04	165 GTO 18	217 ST* 11
13 GTO 11	66 DSE 00	115 GTO 11	166 RCL 22	218 CF 04
14 RCL 22	67 GTO 00	116 RCL 22	167 1/X	219 RCL 00
15 STO 11		117 RCL 13	168 STO 11	220 GTO A
16 STO 12	68*LBL 05	118 *	169 X†2	
17 1	69 RCL 05	119 STO 11	170 STO 12	221*LBL a
18 -	70 RCL 07	120 STO 12	171 1/X	222 XEQ A
19 CHS	71 RTN	121 208	172 SQRT	223 ENTER†
20 STO 21		122 X<=Y?	173 1	224 1
21 ST* 12	72*LBL 11	123 GTO 11	174 -	225 -
22 LN	73 RCL 00	124 X<>Y	175 CHS	226 CHS
23 RCL 13	74 .5	125 CHS	176 STO 21	227 RTN
24 ST* 11	75 +	126 E†X	177 ST* 11	
25 ST* 12	76 RCL 11	127 STO 16	178 ST* 12	228*LBL J
26 *	77 -	128 STO 06	179 RCL 22	229 RCL 13
27 CHS	78 RCL 12	129 STO 07	180 RCL 13	230 -
28 228	79 SQRT	130 SF 03	181 ST* 11	231 XEQ A
29 X<=Y?	80 /		182 ST* 12	232 RCL 21
30 GTO 11	81 STO 10	131*LBL 13	183 Y†X	233 ST/ 11
31 RCL 21	82 XEQ *ZCDF*	132 0	184 STO 16	234 SF 04
32 RCL 13	83 STO 23	133 STO 20	185 STO 06	235 RCL 06
33 Y†X	84 RCL 00	134 RCL 16	186 STO 07	236 RCL 07
34 STO 16	85 .5	135 STO 06	187 SF 01	237 RTN
35 STO 06	86 -	136 STO 07		
36 STO 07	87 RCL 11	137 RCL 00	188*LBL 18	238*LBL D
37 SF 02	88 -	138 X=0?	189 0	239 STO 00
	89 RCL 12	139 GTO 05	190 STO 20	240 FS? 02
38*LBL 07	90 SQRT		191 RCL 16	241 GTO 20
39 0	91 /	140*LBL 14	192 STO 06	242 RCL 22
40 STO 20	92 XEQ *ZCDF*	141 1	193 STO 07	243 1
41 RCL 16	93 RCL 23	142 ST+ 20	194 RCL 00	244 -
42 STO 06	94 -	143 RCL 20	195 X=0?	245 CHS
43 STO 07	95 CHS	144 1/X	196 GTO 05	246 STO 21
44 RCL 00	96 LASTX	145 RCL 11		247 STO 12
45 0	97 SF 04	146 *	197*LBL 19	248 RCL 22
46 X=Y?	98 RTN	147 ST* 06	198 1	249 1/X
47 GTO 05		148 RCL 06	199 ST+ 20	250 STO 11
	99*LBL b	149 ST+ 07	200 RCL 20	251 X†2
48*LBL 08	100 XEQ B	150 DSE 00	201 RCL 13	252 ST* 12
49 1	101 ENTER†	151 GTO 14	202 +	253 SF 02
50 ST+ 20	102 1	152 GTO 05	203 1	
51 RCL 20			204 -	

254•LBL 20	301 .2316419
255 RCL 21	302 *
256 ENTER†	303 +
257 RCL 00	304 1/X
258 1	305 ENTER†
259 -	306 ENTER†
260 Y↑X	307 ENTER†
261 RCL 22	308 1.336274429
262 *	309 *
263 ENTER†	310 -1.821255978
264 ENTER†	311 +
265 RCL 21	312 *
266 RCL 00	313 1.761477937
267 Y↑X	314 +
268 ENTER†	315 *
269 1	316 -.356563782
270 -	317 +
271 CHS	318 *
272 RTH	319 .31938153
	320 +
273•LBL d	321 *
274 XEQ D	322 RCL 04
275 ENTER†	323 *
276 1	324 F67 00
277 -	325 GT0 29
278 CHS	326 PTW
279 RTH	
	327•LBL 27
280•LBL -ZCDF*	328 RCL 03
281 STO 03	329 CHS
282 ENTER†	330 STO 03
283 *	331 XEQ 23
284 2	332 1
285 /	333 X<Y
286 CHS	334 -
287 E↑X	
288 PI	335•LBL 29
289 2	336 CF 00
290 *	337 ENTER†
291 SQRT	338 ENTER†
292 /	339 1
293 STO 04	340 -
294 RCL 03	341 CHS
295 X<0?	342 END
296 GT0 27	
297 SF 00	
298•LBL 23	
299 1	
300 RCL 03	



01*LBL *ZP4*	53*LBL 07	108*LBL 11	158 I	210 /	258*LBL B
02 CF 01	54 RCL 25	109 SF 01	159 -	211 STO 07	259 XEQ *RND
03 FIX 4	55 CHS	110 I	160 CHS	212 I	260 LH
04 0	56 STO 25	111 -	161 RCL 07	213 -	261 RCL 2
05 STOP	57 XEQ 03	112 CHS	162 RTN	214 CHS	262 /
	58 I	113 RTN	163*LBL D	215 RCL 07	263 CHS
06*LBL *ZCDF*	59 X<>Y		164 XEQ C	216 RTN	264 STO 08
07 STO 25	60 -	114*LBL 12	165 STO 08		265 Σ+
08 ENTER↑		115 CF 01	166 X<>Y	217*LBL 15	266 RCL 08
09 *	61*LBL 09	116 STO 19	167 STOP	218 RCL 15	267 RTN
10 2	62 CF 00	117 RTN	168 XEQ C	219 *	
11 /	63 ENTER↑		169 ST- 08	220 RCL 14	268*LBL G
12 CHS	64 ENTER↑	118*LBL *RNDMU*	170 RCL 08	221 -	269 XEQ *RND
13 E+X	65 I	119 RCL 09	171 I	222 CHS	270 XEQ d
14 FI	66 -	120 9321	172 +	223 CF 05	271 STO 08
15 2	67 CHS	121 *	173 RCL 08	224 RTN	272 Σ+
16 *	68 RTN	122 .211377	174 CHS		273 RCL 08
17 SQRT		123 +	175 RTN	225*LBL b	274 RTN
18 /	69*LBL c	124 FRC		226 RCL 12	
19 STO 26	70 .5	125 STO 09	176*LBL d	227 RCL 11	275*LBL *XBAR
20 RCL 25	71 X<>Y	126 RTN	177 XEQ c	228 RTN	276 MEAN
21 X<0?	72 X>Y?		178 RCL 12		277 RTN
22 GTO 07	73 XEQ 11	127*LBL a	179 SQRT	229*LBL E	
23 SF 00	74 ENTER↑	128 XEQ *RNDMU*	180 *	230 STO 08	278*LBL *SD*
	75 *	129 I	181 RCL 11	231 FS? 01	279 SDEV
24*LBL 03	76 I/X	130 RCL 14	182 +	232 GTO 17	280 END
25 I	77 LH	131 +	183 RTN	233 RCL 22	
26 RCL 25	78 SQRT	132 *		234 I/X	
27 .2316419	79 STO 08	133 RCL 13	184*LBL A	235 STO 11	
28 *	80 .010328	134 +	185 STO 08	236 X+2	
29 +	81 *	135 INT	186 FS? 05	237 STO 12	
30 I/X	82 .002053	136 FIX 0	187 GTO 15	238 SF 01	
31 ENTER↑	83 +	137 STOP	188 FS? 01		
32 ENTER↑	84 RCL 08	138 FIX 4	189 GTO 16	239*LBL 17	
33 ENTER↑	85 *	139 Σ+	190 RCL 13	240 RCL 08	
34 1.330274429	86 2.515517	140 RTN	191 RCL 14	241 RCL 22	
35 *	87 +		192 +	242 *	
36 -1.02125597	88 RCL 08	141*LBL *GEN-INT*	193 2	243 CHS	
37 +	89 .001308	142 FIX 4	194 /	244 E+X	
38 *	90 *	143 ΣREG 01	195 STO 11	245 ENTER↑	
39 1.781477937	91 .189269	144 CLE	196 RCL 14	246 ENTER↑	
40 +	92 +	145 *SEED?	197 RCL 13	247 I	
41 *	93 RCL 08	146 PROMPT	198 -	248 -	
42 -.356563782	94 *	147 STO 09	199 STO 15	249 CHS	
43 +	95 1.432783	148 RTN	200 X+2	250 STO 07	
44 *	96 +		201 12	251 RTN	
45 .31930153	97 RCL 08	149*LBL C	202 /		
46 +	98 *	150 RCL 11	203 STO 12	252*LBL e	
47 *	99 I	151 -	204 SF 01	253 LH	
48 RCL 26	100 +	152 RCL 12	205 RCL 08	254 RCL 22	
49 *	101 /	153 SQRT		255 /	
50 FS? 00	102 RCL 08	154 /	206*LBL 16	256 CHS	
51 GTO 09	103 X<>Y	155 STO 10	207 RCL 13	257 RTN	
52 RTN	104 -	156 XEQ *ZCDF*	208 -		
	105 FS? 01	157 STO 07	209 RCL 15		
	106 CHS				
	107 GTO 12				

81*LBL -ZPS-	49 RCL IND 19	183*LBL 03
82 ZREG 01	50 STO 02	184 RCL IND 19
83 CLZ	51 ST* 06	185 STO 09
84 ZREG 07	52 X12	186 1
85 CLZ	53 STO 05	187 ST+ 19
86 ZREG 13	54 1	189 RCL IND 19
87 CLZ	55 ST+ 19	189 STO 18
88 20	56 RCL IND 19	118 1
89 STO 19	57 ST* 01	111 ST+ 19
10 0	58 ST* 02	112 XEQ a
	59 ST* 04	113 STO 07
11*LBL 01	60 ST* 05	114 X12
12 STOP	61 ST* 06	115 STO 03
	62 RCL 01	116 RCL IND 19
13*LBL A	63 ST+ 11	117 ST* 07
14 STO IND 19	64 RCL 02	118 ST* 08
15 STO 09	65 ST+ 13	119 RCL 07
16 1	66 RCL 04	120 ST+ 17
17 ST+ 19	67 ST+ 12	121 RCL 03
18 ST+ 03	68 RCL 05	122 ST+ 18
19 RCL 03	69 ST+ 14	123 1
20 STOP	70 RCL 06	124 ST+ 19
	71 ST+ 15	125 DSE 00
21*LBL B	72 1	126 GTO 03
22 STO IND 19	73 ST+ 19	127 RCL 17
23 STO 10	74 DSE 00	128 X12
24 1	75 GTO 02	129 ST- 18
25 ST+ 19	76 RCL 11	130 RCL 18
26 RCL 03	77 X12	131 RCL 17
27 STOP	78 ST- 12	132 RTN
	79 RCL 13	
28*LBL C	80 X12	133*LBL d
29 STO IND 19	81 ST- 14	134 RCL 11
30 ST+ 07	82 RCL 11	135 STOP
31 STO 03	83 RCL 13	136 RCL 12
32 1	84 *	137 STOP
33 ST+ 19	85 ST- 15	138 RCL 13
34 RCL 03	86 RCL 15	139 STOP
35 GTO 01	87 RCL 12	140 RCL 14
	88 SQRT	141 STOP
36*LBL E	89 /	142 RCL 15
37 RCL 03	90 RCL 14	143 STOP
38 STO 00	91 SQRT	144 RCL 16
39 20	92 /	145 RTN
40 STO 19	93 STO 16	146 GTO d
	94 RTN	
41*LBL 02	95*LBL 0	147*LBL a
42 RCL IND 19	96 0	148 END
43 STO 01	97 STO 17	
44 STO 06	98 STO 13	
45 X12	99 RCL 03	
46 STO 04	100 STO 00	
47 1	101 20	
48 ST+ 19	102 STO 19	

01*LBL *2S-2*	53 +	107 +	161 XEQ C	213 CHS	266 *
02 SREG 01	54 1/X	108 RCL 00	162 ST- 08	214 STO 07	267 RCL 11
03 CLZ	55 ENTER†	109 *	163 RCL 08	215 RTN	268 /
04 FIX 4	56 ENTER†	110 2.515517	164 1		269 RCL 21
05 0	57 ENTER†	111 +	165 +	216*LBL e	270 *
06 STOP	58 1.330274429	112 RCL 00	166 RCL 08	217 1	271 RCL 21
	59 *	113 .001303	167 CHS	218 -	272 /
	60 -1.821255978	114 *	168 RTN	219 CHS	273 ST+ 21
07*LBL *RNDMU*	61 +	115 .109269		220 LN	274 RCL 21
08 RCL 09	62 *	116 +	169*LBL d	221 RCL 16	275 ST+ 26
09 9021	63 1.781477937	117 RCL 00	170 XEQ c	222 /	276 DSE 08
10 *	64 +	118 *	171 RCL 18	223 CHS	277 GTO 06
11 .211377	65 *	119 1.432783	172 *	224 RTN	
12 +	66 -.356563782	120 +	173 RCL 17		278*LBL 08
13 FRC	67 +	121 RCL 00	174 +	225*LBL 20	279 RCL 26
14 STO 09	68 *	122 *	175 RTN	226 *PMTERR?*	280 1
15 RTN	69 .31938153	123 1		227 PROMPT	281 -
	70 +	124 +	176*LBL *GEN-INI*	228 STO 21	282 CHS
16*LBL *RNDMAB*	71 *	125 /	177 FIX 4	229 STO 17	283 RCL 26
17 XEQ *RNDMU*	72 RCL 26	126 RCL 00	178 SREG 01	230 STOP	284 RCL 25
18 RCL 14	73 *	127 X<>Y	179 CLZ	231 STO 22	285 RTN
19 RCL 13	74 FS? 00	128 -	180 *SEED?*	232 ST+ 17	
20 -	75 GTO 09	129 FS? 01	181 PROMPT	233 1	286*LBL *MU-SI*
21 *	76 RTN	130 CHS	182 STO 09	234 -	287 FIX 4
22 RCL 13		131 GTO 12	183 RTN	235 CHS	288 RCL 07
23 +	77*LBL 07			236 STO 23	289 RCL 05
24 RTN	78 RCL 25	132*LBL 11	184*LBL b	237 RCL 22	290 X+2
	79 CHS	133 SF 01	185 XEQ *RNDMU*	238 *	291 -
25*LBL *RNDMI*	80 STO 25	134 1	166 XEQ d	239 RCL 21	292 SORT
26 XEQ *RNDMAB*	81 XEQ 03	135 -	187 STO 00	240 *	293 STO 18
27 INT	82 1	136 CHS	188 Σ+	241 SORT	294 RCL 06
28 FIX 0	83 X<>Y	137 RTN	189 RCL 00	242 STO 10	295 STO 17
29 RTN	84 -		190 RTN	243 0	296 RTN
				244 STOP	
30*LBL 19	85*LBL 09	138*LBL 12	191*LBL B		297*LBL a
31 STO 25	86 CF 00	139 CF 01	192 XEQ *RNDMU*	245*LBL A	298 RCL 18
32 ENTER†	87 ENTER†	140 STO 19	193 XEQ e	246 STO 00	299 RCL 17
33 *	88 ENTER†	141 RTN	194 STO 00	247 RCL 23	300 RTN
34 2	89 1		195 Σ+	248 RCL 21	
35 /	90 -	142*LBL C	196 RCL 00	249 Y+X	301*LBL *BSI*
36 CHS	91 CHS	143 STO 00	197 RTN	250 STO 24	302 XPOM *EBSI*
37 E+X	92 RTN	144 RCL 17		251 STO 25	303 RTN
38 PI		145 -	198*LBL E	252 STO 26	
39 2	93*LBL c	146 RCL 18	199 STO 00	253 0	304*LBL *XB*
40 *	94 .5	147 /	200 RCL 16	254 STO 10	305 MEAN
41 SORT	95 X<>Y	148 STO 20	201 1/X	255 RCL 00	306 PTN
42 /	96 X>Y?	149 XEQ 19	202 STO 17	256 X=Y?	
43 STO 26	97 XEQ 11	150 STO 07	203 STO 18	257 GTO 03	307*LBL *S
44 RCL 25	98 ENTER†	151 1	204 RCL 00		308 SDEV
45 X<0?	99 *	152 -	205 RCL 16	258*LBL 06	309 RTN
46 GTO 07	100 1/X	153 CHS	206 *	259 1	
47 SF 00	101 LN	154 RCL 07	207 CHS	260 ST+ 10	310*LBL *S
	102 SORT	155 RTN	208 E+X	261 RCL 10	311 RDN
48*LBL 03	103 STO 00		209 ENTER†	262 CHS	312 RTN
49 1	104 .010328	156*LBL D	210 ENTER†	263 RCL 21	313 END
50 RCL 25	105 *	157 XEQ C	211 1	264 +	
51 .2316419	106 .002053	158 STO 00	212 -	265 1	
52 *		159 X<>Y			
		160 STOP			

01+LBL \*2S-3\*

02 STOP

03+LBL C

04 RCL 13

05 RCL 12

06 -

07 RTH

08+LBL B

09 MEAN

10 STO 00

11 RCL 06

12 STO 00

13 31

14 STO 30

15 0

16 STO 07

17+LBL 01

18 RCL IND 30

19 RCL 00

20 -

21 RES

22 ST+ 07

23 1

24 ST+ 30

25 DSE 00

26 GTO 01

27 RCL 07

28 RCL 06

29 /

30 RTH

31+LBL b

32 MEAN

33 STO 00

34 RCL 19

35 STO 00

36 31

37 STO 14

38 32

39 STO 15

40 0

41 STO 07

42+LBL 02

43 RCL IND 14

44 RCL 00

45 -

46 RES

47 RCL IND 15

48 \*

49 ST+ 07

50 2

51 ST+ 14

52 ST+ 15

53 DSE 00

54 GTO 02

55 RCL 07

56 RCL 06

57 /

58 RTH

59+LBL c

60 RCL 13

61 +

62 RCL 12

63 -

64 RTH

65+LBL d

66 CF 01

67 0

68 RTH

69+LBL D

70 FS? 01

71 GTO 03

72 30

73 STO 00

74+LBL 03

75 1

76 ST+ 00

77 RCL IND 00

78 SF 01

79 RTH

80+LBL e

81 CF 01

82 ΣREG 07

83 CLΣ

84 ΣREG 13

85 CLΣ

86 ΣREG 01

87 CLΣ

88 SF 07

89 31

90 STO 15

91 STO 30

92 0

93 STO 19

94 RTH

95+LBL E

96 STO 14

97+LBL 04

98 RCL IND 15

99 XEQ a

100 XEQ 05

101 1

102 ST+ 15

103 DSE 14

104 GTO 04

105 RCL 19

106 RTH

107+LBL A

108 XEQ a

109+LBL 05

110 STO 03

111 STO IND 30

112 FS? 07

113 XEQ 13

114 ST+ 01

115 RCL 09

116 \*

117 ST+ 02

118 1

119 ST+ 06

120 ST+ 19

121 ST+ 30

122 RCL 12

123 RCL 09

124 X&lt;=Y?

125 STO 12

126 RCL 13

127 X&lt;&gt;Y

128 X&gt;Y?

129 STO 13

130 RCL 19

131 RTH

132+LBL 13

133 STO 12

134 STO 13

135 CF 07

136 RTH

137+LBL \*MSD\*

138 SDEV

139 STO 00

140 RDN

141 XEQ 12

142 RCL 00

143 XEQ 12

144 RTH

145+LBL 12

146 X12

147 RCL 06

148 1

149 -

150 \*

151 RCL 06

152 /

153 RTH

154+LBL \*XBAR\*

155 MEAN

156 RTH

157+LBL \*SD\*

158 SDEV

159 RTH

160+LBL a

161 END

01\*LBL "ST-03"  
02 0  
03 STOP

04\*LBL e  
05 ΣREG 01  
06 CF 06  
07 CLRG  
08 31  
09 STO 30  
10 1  
11 STO 10  
12 SF 07  
13 0  
14 STOP

15\*LBL A  
16 STO 10  
17 STO IND 30  
18 FS? 06  
19 GTO 01  
20 1  
21 ST+ 30

22\*LBL 02  
23 RCL 10  
24 STO 09  
25 FS? 07  
26 XEQ 03  
27 RCL 10  
28 \*  
29 ST+ 01  
30 RCL 09  
31 \*  
32 ST+ 02  
33 RCL 10  
34 ST+ 06  
35 1  
36 ST+ 19  
37 RCL 12  
38 RCL 09  
39 X<=Y?  
40 STO 12  
41 RCL 13  
42 X<>Y  
43 X>Y?  
44 STO 13  
45 RCL 19  
46 RTH

47\*LBL B  
48 STO 10  
49 1  
50 ST+ 30  
51 RCL 10  
52 STO IND 30  
53 1  
54 ST- 30  
55 SF 06  
56 RCL 10  
57 RTH  
  
58\*LBL 01  
59 2  
60 ST+ 30  
61 GTO 02

62\*LBL 03  
63 STO 12  
64 STO 13  
65 CF 07  
66 END

01\*LBL "ST-07/9"  
02 0  
03 STOP

04\*LBL e  
05 ΣREG 12  
06 CLΣ  
07 ΣREG 10  
08 CLΣ  
09 ΣREG 24  
10 CLΣ  
11 ΣREG 01  
12 CLΣ  
13 31  
14 STO 30  
15 0  
16 STO 00  
17 "CELLS?"  
18 PROMPT  
19 STO 09  
20 "XMIN?"  
21 PROMPT  
22 STO 12  
23 "W=?"  
24 PROMPT  
25 STO 11  
26 RCL 09  
27 \*  
28 RCL 12  
29 +  
30 STO 13  
31 0  
32 RTH

33\*LBL A  
34 STO 00  
35 STO IND 30  
36 RCL 13  
37 X<=Y?  
38 GTO 01  
39 RDN  
40 RCL 12  
41 X>Y?  
42 GTO 01  
43 -  
44 RCL 11  
45 /  
46 INT  
47 14  
48 +  
49 STO 00  
50 1  
51 ST+ 29  
52 ST+ 30

53 ST+ IND 00  
54 ST+ 06  
55 RCL 03  
56 ST+ 01  
57 RCL 03  
58 \*  
59 ST+ 02  
60 RCL 29  
61 RTH

62\*LBL 01  
63 0  
64 /  
65 RTH  
  
66\*LBL d  
67 "N=?"  
68 PROMPT  
69 31  
70 STO 30  
71 +  
72 STO 05

73\*LBL 02  
74 RCL IND 30  
75 XEQ A  
76 RCL 05  
77 RCL 30  
78 X=Y?  
79 GTO 03  
80 GTO 02  
  
81\*LBL 03  
82 RCL 29  
83 RTH

84\*LBL c  
85 1  
86 ST+ 00  
87 ST+ 10  
88 RCL 09  
89 RCL 00  
90 X<=Y?  
91 GTO 04  
92 "STOP"  
93 PROMPT  
94 STOP

95\*LBL 04  
96 RCL IND 10  
97 STO 07  
98 STO 05  
99 FIX 0  
100 STOP  
101 FIX 4

102 RCL 11  
103 RCL 00  
104 \*  
105 RCL 12  
106 +  
107 STO 05  
108 RCL 11  
109 2  
110 /  
111 -  
112 ST\* 07  
113 ST\* 08  
114 ST\* 08  
115 RCL 07  
116 ST+ 03  
117 RCL 08  
118 ST+ 04  
119 RCL 05  
120 RTH

121\*LBL E  
122 13  
123 STO 10  
124 0  
125 STO 00  
126 STO 03  
127 STO 04  
128 END



01*LBL *ZS-4/5*	52 STO 15	100*LBL E
02 *DATA?*	53 FS? 04	101 RCL 37
03 PROMPT	54 GTO 02	102 STO 40
04 ΣREG 01	55 STOP	103 RCL 06
05 CLΣ	56 STO 31	104 2
06 0	57 XEQ *CI*	105 *
	58 STOP	106 STO 15
		107 GTO 06
07*LBL 01	59*LBL 02	
08 STOP	60 RCL 30	108*LBL 5
09 Σ+	61 XEQ *TF*	109 XEQ *HYP*
10 GTO 01	62 XEQ *PVAL*	
	63 STOP	
11*LBL D		110*LBL B
12 XEQ *ZA*	64*LBL c	111 STO 00
13 RCL 15	65 XEQ *HYP*	112 SF 05
14 9		113 RCL 48
15 *	66*LBL C	114 STO 30
16 2	67 RCL 39	115 GTO A
17 /	68 X+2	
18 1/X	69 STO 40	116*LBL 04
19 STO 49	70 RCL 06	117 CF 05
20 SQRT	71 1	118 FS? 04
21 *	72 -	119 GTO 05
22 RCL 49	73 STO 15	120 RCL 00
23 -		121 XEQ *ZA*
24 1	74*LBL 06	122 STO 31
25 +	75 FS? 04	123 XEQ *CI*
26 3	76 GTO 07	124 RTH
27 Y+X		
28 RCL 15	77*LBL 03	125*LBL 05
29 *	78 STOP	126 XEQ *ZCDF*
30 GTO 03	79 RCL 15	127 XEQ *PVAL*
	80 RCL 40	128 STOP
31*LBL a	81 *	
32 XEQ *HYP*	82 STO 00	129*LBL d
	83 RCL 41	130 MEAN
33*LBL A	84 /	131 STO 37
34 RCL 37	85 RCL 00	132 SDEV
35 STO 40	86 RCL 31	133 STO 38
36 RCL 38	87 /	134 0
37 RCL 06	88 STOP	135 RTH
38 SQRT		136 END
39 /	89*LBL 07	
40 STO 32	90 RCL 40	
41 1/X	91 *	
42 RCL 40	92 RCL 34	
43 RCL 34	93 /	
44 -	94 STO 30	
45 *	95 XEQ *CHISD*	
46 STO 30	96 XEQ *PVAL*	
47 FS? 05	97 STOP	
48 GTO 04		
49 RCL 06	98*LBL e	
50 1	99 XEQ *HYP*	
51 -		



01•LBL "ZS-6"	44•LBL 12	98•LBL 01	145 GTO 05	197•LBL 06
02 "DATA?"	45 MEAN	99 STO 15	146 RCL 13	198 RCL 06
03 PROMPT	46 STO 37	100 FS? 04	147 1	199 1
04 STOP	47 SDEV	101 GTO 03	148 -	200 -
	48 STO 38	102 STOP	149 STO 15	
05•LBL "DEP"	49 0	103 STO 31	150 RCL 48	201•LBL 07
06 SF 01	50 STO 33	104 XEQ "CI"	151 X12	202 STO 16
07 11	51 RTN	105 STOP	152 *	203 FS? 04
08 GTO 08			153 STO 00	204 GTO 08
	52•LBL a	106•LBL 02	154 RCL 06	205 STOP
09•LBL "DEI"	53 XEQ "HYP"	107 CF 05	155 1	206 RCL 41
10 CF 01		108 RCL 30	156 -	207 RCL 30
11 12	54•LBL A	109 XEQ "ZCDF"	157 ST+ 15	208 *
	55 XEQ "DMS"	110 XEQ "PYAL"	158 RCL 30	209 ENTER↑
12•LBL 00	56 RCL 48	111 STOP	159 X12	210 ENTER↑
13 SREG 01	57 X12		160 *	211 RCL 30
14 STO 10	58 RCL 13	112•LBL 03	161 RCL 00	212 RCL 31
15 CLΣ	59 /	113 RCL 30	162 +	213 /
16 0	60 STO 07	114 XEQ "TF"	163 RCL 15	214 CF 01
	61 RCL 39	115 XEQ "PYAL"	164 /	215 CF 02
17•LBL 13	62 X12	116 STOP	165 SQR	216 RTN
18 STOP	63 RCL 06		166 STO 33	
19 FS? 01	64 /	117•LBL 04		217•LBL 08
20 -	65 STO 08	118 STO 32	167•LBL 05	218 RCL 30
21 Σ+	66 RCL 07	119 RCL 40	168 RCL 06	219 XEQ "FCDF"
22 GTO 13	67 +	120 RCL 34	169 1/X	220 XEQ "PYAL"
	68 SQR	121 -	170 RCL 13	221 STOP
23•LBL "X TO Y"	69 XEQ 04	122 RCL 32	171 1/X	
24 MEAN	70 FS? 05	123 /	172 +	222•LBL c
25 STO 47	71 GTO 02	124 STO 30	173 SQR	223 STO 20
26 SDEV	72 RCL 07	125 RTN	174 RCL 33	224 RCL 47
27 STO 48	73 RCL 08		175 *	225 RCL 37
28 RCL 06	74 +	126•LBL b	176 XEQ 04	226 /
29 STO 13	75 RCL 07	127 XEQ "HYP"	177 RCL 13	227 STO 30
30 CLΣ	76 /		178 2	228 RCL 13
31 0	77 1/X	128•LBL 8	179 -	229 2
32 GTO 13	78 STO 09	129 XEQ "DMS"	180 RCL 06	230 *
	79 CHS	130 RCL 27	181 +	231 STO 15
33•LBL d	80 1	131 RCL 06	182 GTO 01	232 FS? 04
34 GTO IND 10	81 +	132 SQR		233 GTO 09
	82 X12	133 /	183•LBL d	234 STOP
35•LBL 11	83 RCL 06	134 XEQ 04	184 STO 36	
36 MEAN	84 1	135 RCL 06	185 RCL 48	235•LBL 09
37 STO 47	85 -	136 1	186 RCL 30	236 RCL 06
38 SDEV	86 /	137 -	187 /	237 2
39 STO 27	87 STO 00	138 GTO 01	188 X12	238 *
40 0	88 RCL 09		189 STO 30	239 GTO 07
41 STO 37	89 X12	139•LBL c	190 RCL 13	240 END
42 CF 01	90 RCL 13	140 XEQ "HYP"	191 1	
43 RTN	91 1		192 -	
	92 -	141•LBL C	193 STO 15	
	93 /	142 XEQ "DMS"	194 FS? 04	
	94 RCL 00	143 RCL 33	195 GTO 06	
	95 +	144 X=0?	196 STOP	
	96 1/X			
	97 INT			

01\*LBL \*ZS-7\*  
 02 0  
 03 STOP  
  
 04\*LBL C  
 05 XEQ \*ZA\*  
 06 STO 31  
 07 RCL 06  
 08 STO 00  
 09 RCL 40  
 10 XEQ 03  
 11 RCL 31  
 12 XEQ \*CI\*  
 13 STO 05  
 14 X<>Y  
 15 STO 04  
 16 X<>Y  
 17 X>0?  
 18 GTO 01  
 19 0  
 20 STO 05  
  
 21\*LBL 01  
 22 RCL 04  
 23 1  
 24 X>Y?  
 25 GTO 02  
 26 ENTER†  
  
 27\*LBL 02  
 28 RDM  
 29 RCL 05  
 30 RTN  
  
 31\*LBL 03  
 32 ENTER†  
 33 ENTER†  
 34 1  
 35 -  
 36 CHS  
 37 \*  
 38 RCL 00  
 39 /  
 40 SQRT  
 41 STO 32  
 42 RTN  
  
 43\*LBL 8  
 44 RCL 40  
 45 RCL 06  
 46 \*  
 47 RMD  
 48 STO 19  
 49 RCL 06

50 -  
 51 CHS  
 52 STO 22  
 53 1  
 54 +  
 55 2  
 56 \*  
 57 STOP  
 58 RCL 18  
 59 2  
 60 \*  
 61 STOP  
 62 RCL 18  
 63 1  
 64 +  
 65 STO 19  
 66 2  
 67 \*  
 68 STOP  
 69 RCL 06  
 70 RCL 18  
 71 -  
 72 STO 22  
 73 2  
 74 \*  
 75 STOP  
 76 RCL 19  
 77 RCL 41  
 78 \*  
 79 ENTER†  
 80 ENTER†  
 81 RCL 22  
 82 +  
 83 /  
 84 STO 04  
 85 RCL 22  
 86 1  
 87 +  
 88 RCL 31  
 89 \*  
 90 RCL 19  
 91 +  
 92 1/X  
 93 RCL 18  
 94 \*  
 95 STO 05  
 96 RCL 04  
 97 X<>Y  
 98 RTN

99\*LBL b  
 100 STO 28  
 101 STOP  
 102 STO 34  
 103 RCL 06  
 104 RCL 40  
 105 \*  
 106 RMD  
 107 STO 30  
 108 RCL 28  
 109 X>Y?  
 110 GTO 05  
 111 1  
 112 X\*Y?  
 113 GTO 04  
 114 CHS  
 115 RCL 30  
 116 +  
 117 STO 30  
  
 118\*LBL 04  
 119 RCL 30  
 120 XEQ \*BINF\*  
 121 XEQ \*PVAL\*  
 122 STOP  
  
 123\*LBL 05  
 124 1  
 125 STOP  
  
 126\*LBL c  
 127 STO 34  
 128 RCL 40  
 129 -  
 130 CHS  
 131 STO 23  
 132 RCL 06  
 133 STO 00  
 134 RCL 34  
 135 XEQ 03  
 136 RCL 23  
 137 X<>Y  
 138 /  
  
 139\*LBL 06  
 140 STO 30  
 141 XEQ \*ZCDF\*  
 142 XEQ \*PVAL\*  
 143 STOP

144\*LBL A  
 145 XEQ \*ZA\*  
 146 STO 31  
 147 XEQ \*DMS\*  
 148 RCL 13  
 149 STO 00  
 150 RCL 47  
 151 XEQ 03  
 152 X†2  
 153 STO 27  
 154 RCL 06  
 155 STO 00  
 156 RCL 37  
 157 XEQ 03  
 158 X†2  
 159 RCL 27  
 160 +  
 161 SQRT  
 162 STO 32  
 163 RCL 31  
 164 XEQ \*CI\*  
 165 STOP  
  
 166\*LBL a  
 167 STO 28  
 168 RCL 13  
 169 1/X  
 170 RCL 06  
 171 1/X  
 172 +  
 173 STO 33  
 174 RCL 13  
 175 STO 00  
 176 RCL 47  
 177 \*  
 178 ENTER†  
 179 RCL 06  
 180 ST+ 00  
 181 RCL 37  
 182 \*  
 183 +  
 184 RCL 00  
 185 /  
 186 STO 00  
 187 1  
 188 -  
 189 CHS  
 190 ST\* 00  
 191 RCL 00  
 192 ST\* 33  
 193 XEQ \*DMS\*  
 194 RCL 33  
 195 SQRT  
 196 STO 32  
 197 /  
 198 GTO 06  
 199 END

01*LBL "2S-8"	52 +	103 ST+ 53
02 FIX 4	53 LASTX	104 STOP
03 STOP	54 RCL 49	105 STO 52
	55 -	106 RCL 51
04*LBL A	56 RTH	107 *
05 STO 30		108 ST+ 50
06 RCL 03	57*LBL C	109 1
07 STO 15	58 STO 57	110 ST+ 54
08 RCL 02	59 RCL 12	111 RCL 54
09 RCL 11	60 RCL 14	112 GTO 02
10 STO 16	61 STO 58	
11 /	62 STO 16	113*LBL D
12 STO 48	63 /	114 ENTER†
13 RCL 30	64 RCL 07	115 RCL 58
14 XEQ "FCCDF"	65 /	116 *
15 STO 31	66 STO 56	117 RCL 48
16 RTH	67 RCL 14	118 *
	68 RCL 12	119 RCL 53
17*LBL e	69 /	120 *
18 0	70 1/X	121 RCL 59
19 STO 53	71 STOP	122 1
20 STO 54	72 RCL 15	123 +
21 STO 50	73 STO 59	124 /
	74 ST+ 16	
22*LBL 01	75 RCL 13	125*LBL 03
23 STOP	76 /	126 SORT
24 STO 51	77 1/X	127 STO 49
25 STOP	78 STOP	128 RCL 50
26 STO 52	79 RCL 07	129 +
27 STOP	80 STO 48	130 LASTX
28 1/X	81 STOP	131 RCL 49
29 RCL 51	82 RCL 50	132 -
30 X12	83 STO 15	133 RTH
31 *	84 RCL 56	
32 ST+ 53	85 XEQ "FCCDF"	134*LBL d
33 RCL 51	86 STO 30	135 RCL 59
34 RCL 52	87 RCL 59	136 *
35 *	88 STO 15	137 RCL 40
36 ST+ 50	89 RCL 30	138 *
37 1	90 STOP	139 RCL 53
38 ST+ 54	91 RCL 57	140 *
39 RCL 54	92 XEQ "FCCDF"	141 RCL 50
40 GTO 01	93 RTH	142 1
		143 +
41*LBL a	94*LBL E	144 /
42 ENTER†	95 0	145 GTO 03
43 RCL 03	96 STO 53	
44 *	97 STO 50	146*LBL H
45 RCL 48	98 STO 54	147 XROM "SAOVONE"
46 *		
47 RCL 53	99*LBL 02	148*LBL I
48 *	100 STOP	149 XROM "SAOV TWO"
49 SORT	101 STO 51	150 .END.
50 STO 49	102 X12	
51 RCL 50		

1•LBL *25-9-	53 RCL 04	106 ENTER†	155•LBL 03	207•LBL 2	263 RCL 43
02 0	54 *	107 MEAN	156 RCL 31	208 STO 30	264 *
03 FIX 4	55 RCL 06	108 STO 43	157 *	209 0	265 RCL 42
04 STOP	56 /	109 RDN	158 STO 39	210 STO 34	266 /
	57 RCL 08	110 STO 47	159 RCL 00	211 RCL 44	267 RCL 47
05•LBL D	58 /	111 *	160 XEQ *OP14-	212 STO 40	268 *
06 ΣREG 01	59 SQRT	112 CHS	161 STO 40	213 X12	269 STO 40
07 CLRG	60 STO 36	113 R†	162 GTO 02	214 1	270 GTO 02
08 0	61 RCL 33	114 +		215 -	
	62 RCL 08	115 STO 46	163•LBL c	216 CHS	271•LBL 06
09•LBL 01	63 SQRT	116 RCL 45	164 XEQ 04	217 SQRT	272 *ALL PEARLS*
10 STOP	64 /	117 X<Y	165 X12	218 1/X	273 AVIEW
11 Σ+	65 STO 35	118 RTH	166 RCL 33	219 RCL 15	274 RTH
12 GTO 01	66 RCL 15		167 X12	220 SQRT	275 END
	67 STOP	119•LBL *OP14-	168 +	221 *	
13•LBL e	68 STO 31	120 RCL 45	169 SQRT	222 RCL 40	
14 RCL 06	69 RTH	121 *	170 STO 37	223 *	
15 1		122 RCL 46	171 GTO 03	224 GTO 05	
16 -	70•LBL *OP13-	123 +			
17 STO 14	71 RCL 05	124 RTH	172•LBL 04	225•LBL d	
18 1	72 RCL 06		173 STO 00	226 RCL 40	
19 -	73 *	125•LBL *OP15-	174 RCL 47	227 -	
20 STO 15	74 ENTER†	126 RCL 46	175 -	228 STO 43	
21 SDEV	75 ENTER†	127 -	176 X12	229 X12	
22 X12	76 RCL 01	128 RCL 45	177 RCL 00	230 RCL 00	
23 RCL 14	77 RCL 03	129 /	178 /	231 /	
24 *	78 *	130 RTH	179 RCL 06	232 STO 00	
25 STO 07	79 -		180 1/X	233 RCL 33	
26 RDN	80 RCL 06	131•LBL 0	181 +	234 RCL 31	
27 X12	81 /	132 RCL 31	182 SQRT	235 *	
28 RCL 14	82 LASTX	133 RCL 35	183 RCL 33	236 X12	
29 *	83 1	134 *	184 *	237 RCL 00	
30 STO 03	84 -	135 STO 39	185 STO 38	238 /	
31 RCL 07	85 /	136 RCL 45	186 RTH	239 RCL 45	
32 *	86 ENTER†	137 STO 40		240 X12	
33 SQRT	87 ENTER†		187•LBL 0	241 -	
34 ENTER†	88 SDEV	138•LBL 02	188 XEQ *HYP-	242 CHS	
35 XEQ *OP12-	89 RDN	139 RCL 39	189 RCL 45	243 STO 42	
36 X<Y	90 /	140 +	190 -	244 RCL 06	
37 RCL 44	91 R†	141 RCL 40	191 CHS	245 /	
38 *	92 /	142 LASTX	192 RCL 35	246 RCL 42	
39 RCL 08	93 STO 44	143 -	193 /	247 +	
40 SQRT	94 RTH	144 STOP		248 RCL 00	
41 *			194•LBL 05	249 +	
42 RCL 07	95•LBL *OP12-	145•LBL 0	195 STO 30	250 0	
43 SQRT	96 XEQ *OP13-	146 RCL 31	196 XEQ *TF-	251 X1Y?	
44 *	97 ENTER†	147 RCL 36	197 XEQ *PVAL-	252 GTO 06	
45 CHS	98 ENTER†	148 *	198 STOP	253 X<Y	
46 RCL 07	99 SDEV	149 STO 39		254 SQRT	
47 +	100 RDN	150 RCL 46	199•LBL b	255 RCL 31	
48 RCL 15	101 /	151 STO 40	200 XEQ *HYP-	256 *	
49 /	102 R†	152 GTO 02	201 RCL 46	257 RCL 33	
50 SQRT	103 *		202 -	258 *	
51 STO 33	104 STO 45	153•LBL C	203 CHS	259 RCL 42	
52 X12	105 ENTER†	154 XEQ 04	204 RCL 36	260 /	
			205 /	261 STO 39	
			206 GTO 05	262 RCL 45	

01\*LBL \*2S-10\*

02 FIX 4  
03 CF 01  
04 CF 04  
05 0  
06 STOP

07\*LBL e  
08 RCL 41  
09 STO 07  
10 RCL 01  
11 STO 46  
12 RCL 42  
13 STO 11  
14 RCL 02  
15 STO 47  
16 RCL 43  
17 STO 12  
18 RCL 03  
19 STO 43  
20 RCL 33  
21 STO 01  
22 RCL 33  
23 STO 02  
24 RCL 31  
25 STO 03  
26 3  
27 -  
28 STO 15  
29 RCL 32  
30 STO 04  
31 RCL 35  
32 STO 05  
33 RCL 36  
34 STO 06  
35 RCL 30  
36 STO 13  
37 RCL 03  
38 RCL 05  
39 \*  
40 RCL 02  
41 \*  
42 STO 49  
43 2  
44 RCL 04  
45 \*  
46 RCL 01  
47 \*  
48 RCL 06  
49 \*  
50 ST+ 49  
51 RCL 03  
52 RCL 06  
53 X12

54 \*  
55 ST- 49  
56 RCL 04  
57 X12  
58 RCL 02  
59 \*  
60 ST- 49  
61 RCL 01  
62 X12  
63 RCL 05  
64 \*  
65 ST- 49  
66 RCL 13  
67 STO 33  
68 RCL 46  
69 RCL 07  
70 \*  
71 ST- 33  
72 RCL 47  
73 RCL 11  
74 \*  
75 ST- 33  
76 RCL 40  
77 RCL 12  
78 \*  
79 ST- 33  
80 RCL 33  
81 RCL 15  
82 /  
83 SQRT  
84 STO 33  
85 RCL 05  
86 RCL 02  
87 \*  
88 RCL 06  
89 X12  
90 -  
91 RCL 49  
92 /  
93 SQRT  
94 RCL 33  
95 \*  
96 STO 36  
97 RCL 03  
98 RCL 02  
99 \*  
100 RCL 01  
101 X12  
102 -  
103 RCL 49  
104 /  
105 SQRT  
106 RCL 33  
107 \*

108 STO 37  
109 RCL 03  
110 RCL 05  
111 \*  
112 RCL 04  
113 X12  
114 -  
115 RCL 49  
116 /  
117 SQRT  
118 RCL 33  
119 \*  
120 STO 30  
121 RCL 07  
122 RCL 03  
123 /  
124 STO 03  
125 RCL 27  
126 STO 44  
127 RCL 15  
128 STOP  
129 STO 31  
130 RTN  
131\*LBL A  
132 RCL 46  
133 STO 40  
134 RCL 31  
135 RCL 36  
136 \*  
137 STO 39  
138\*LBL 01  
139 RCL 40  
140 +  
141 ENTER↑  
142 ENTER↑  
143 RCL 39  
144 2  
145 \*  
146 -  
147 RTN  
148\*LBL B  
149 RCL 47  
150 STO 40  
151 RCL 31  
152 RCL 37  
153 \*  
154 STO 39  
155 GTO 01

156\*LBL C  
157 RCL 48  
158 STO 40  
159 RCL 31  
160 RCL 30  
161 \*  
162 STO 39  
163 GTO 01  
164\*LBL a  
165 XEQ \*HYP-  
166 RCL 46  
167 -  
168 CHS  
169 RCL 36  
170 /  
171\*LBL 02  
172 STO 30  
173 XEQ \*TF-  
174 XEQ \*PVAL-  
175 STOP  
176\*LBL b  
177 XEQ \*HYP-  
178 RCL 47  
179 -  
180 CHS  
181 RCL 37  
182 /  
183 GTO 02  
184\*LBL c  
185 XEQ \*HYP-  
186 RCL 40  
187 -  
188 CHS  
189 RCL 30  
190 /  
191 GTO 02  
192\*LBL E  
193 RCL 47  
194 \*  
195 STO 00  
196 0  
197 STOP  
198 RCL 48  
199 \*  
200 ST+ 00  
201 RCL 46  
202 ST+ 00  
203 RCL 00  
204 RTN

205\*LBL d  
206 RCL 46  
207 STOP  
208 RCL 47  
209 STOP  
210 RCL 40  
211 STOP

212\*LBL d  
213 XPO\* \*ENLRY-  
214 END



01*LBL *ZSTAT*	52*LBL 02	104 CHS	153 -	200 Y12
02 *ZSTAT*	53 RCL 25	105 GT0 05	154 Y1X	207 1
03 PROMPT	54 CHS	106*LBL 04	155 RCL 30	208 -
04 RTN	55 STO 25	107 SF 01	156 2	209 RCL 29
05*LBL *ZCDF*	56 XEQ 01	108 1	157 -	210 +
06 STO 25	57 1	109 -	158 CHS	211 RCL 29
07 ENTER†	58 X<>Y	110 CHS	159 E1X	212 S9FT
08 *	59 -	111 RTN	160 *	213 /
09 2	60*LBL 03	112*LBL 05	161 2	214 XEQ *ZCDF*
10 /	61 CF 00	113 CF 01	162 RCL 21	215 RTN
11 CHS	62 ENTER†	114 RTN	163 Y1X	216*LBL *FCCIF*
12 E1X	63 1	115*LBL *CHISD*	164 /	217 STO 17
13 PI	64 -	116 STO 30	165 RCL 23	218 RCL 15
14 2	65 CHS	117 40	166 /	219 2
15 *	66 RTN	118 RCL 15	167 STO 25	220 /
16 S9FT	67*LBL *ZA*	119 X<>Y?	168 RCL 30	221 FRC
17 /	68 .5	120 GT0 10	169 RCL 21	222 0
18 STO 26	69 X<>Y	121 1	170 /	223 X*Y?
19 RCL 25	70 X<>Y?	122 STO 23	171 ST* 25	224 SF 01
20 X<02	71 XEQ 04	123 X<>Y	172 2	225 RCL 16
21 GT0 02	72 ENTER†	124 2	173 RCL 21	226 2
22 SF 00	73 *	125 /	174 *	227 /
23*LBL 01	74 1/X	126 STO 21	175 STO 26	228 FFC
24 1	75 LN	127 INT	176 1	229 0
25 RCL 25	76 SQRT	128 LASTX	177 STO 24	230 X*Y?
26 .2316419	77 STO 25	129 X*Y?	178*LBL 09	231 SF 02
27 *	78 .010320	130 GT0 06	179 RCL 30	232 FSC 01
28 +	79 *	131 1	180 RCL 26	233 GT0 16
29 1/X	80 .002053	132 -	181 2	234 FSC 02
30 ENTER†	81 +	133 FACT	182 +	235 GT0 11
31 ENTER†	82 RCL 25	134 STO 23	183 STO 26	236 RCL 15
32 ENTER†	83 *	135 GT0 06	184 /	237 RCL 16
33 1.338274429	84 2.515517	136*LBL 06	185 RCL 24	238 X<=Y?
34 *	85 +	137 .5	186 *	239 GT0 17
35 -1.021255978	86 RCL 25	138 X=Y?	187 STO 24	240*LBL 11
36 +	87 .001300	139 GT0 07	188 +	241 CF 02
37 *	88 *	140 X<>Y	189 X*Y?	242 RCL 15
38 1.781477937	89 .189269	141 1	190 GT0 09	243 STO 18
39 +	90 +	142 -	191 RCL 25	244 RCL 16
40 *	91 RCL 25	143 ST* 23	192 *	245 STO 19
41 -.356563782	92 *	144 GT0 06	193 PTN	246 STO 25
42 +	93 1.432788	145*LBL 07	194*LBL 10	247 XEQ 15
43 *	94 +	146 PI	195 9	248 STO 28
44 .31938153	95 RCL 25	147 SQRT	196 *	249 CHS
45 +	96 *	148 ST* 23	197 2	250 STO 21
46 *	97 1	149*LBL 08	198 /	251*LBL 12
47 RCL 26	98 +	150 RCL 30	199 1/X	252 RCL 18
48 *	99 /	151 RCL 21	200 STO 29	253 2
49 FSC 00	100 RCL 25	152 1	201 RCL 30	254 /
50 GT0 03	101 X<>Y		202 RCL 15	255 STO 00
51 RTN	102 -		203 /	256 1
	103 FSC 01		204 3	257 ST* 21
			205 1/X	



## ZSTAT (cont'd)

258 STO 22	303 STO 19	361 2	412 -	462 RCL 06	513 *
259 STO 23	309 STO 25	362 *	413 STO 25	463 RCL 00	514 STO 39
260 STO 24	310 XEQ 15	363 RCL 25		464 -	515 RCL 40
	311 STO 21	364 /	414*LBL 24	465 ST/ 35	516 +
261*LBL 13	312 CHS	365 ST* 23	415 2	466 2	517 ENTER↑
262 RCL 22	313 STO 20	366 RCL 23	416 ST+ 25	467 *	518 ENTER↑
263 RCL 00	314 1	367 ST+ 22	417 ST+ 26	468 STO 16	519 RCL 39
264 X<=Y?	315 ST+ 20	368 1	418 RCL 26	469 RCL 35	520 2
265 GT0 14	316 ST- 21	369 ST+ 24	419 RCL 15	470 1/X	521 *
266 X<>Y	317 XEQ 12	370 GT0 19	420 X<=Y?	471 RCL 34	522 -
267 1/X	318 CHS		421 GT0 25	472 *	523 RTH
269 RCL 21	319 1	371*LBL 20	422 RCL 26	473 1	
269 *	320 +	372 RCL 20	423 1/X	474 RCL 34	524*LBL "HYP"
270 RCL 19	321 RTH	373 ST* 22	424 RCL 25	475 -	525 STO 28
271 *		374 RCL 22	425 *	476 /	526 STOP
272 2	322*LBL 18	375 ST+ 17	426 RCL 20	477 XEQ "FCCDF"	527 STO 34
273 ST+ 19	323 CF 02		427 X↑2	478 RTH	528 SF 04
274 /	324 RCL 17	376*LBL 21	428 *		529 RTH
275 ST* 23	325 RCL 15	377 1	429 ST* 27	479*LBL "TF"	
276 1	326 *	378 STO 22	430 RCL 27	480 STO 30	530*LBL "PVAL"
277 ST+ 22	327 RCL 16	379 1	431 ST+ 22	481 40	531 STO 29
278 RCL 23	328 /	380 STO 24	432 GT0 24	482 RCL 15	532 CF 04
279 ST+ 24	329 SART	381 RCL 15		483 X<>Y?	533 RCL 28
280 GT0 13	330 RAD	382 X=Y?	433*LBL 25	484 GT0 28	534 X<0?
	331 ATAN	383 GT0 26	434 RCL 22	485 STO 16	535 GT0 30
281*LBL 14	332 STO 17	384 RDN	435 RCL 24	486 1	536 X*0?
282 RCL 20	333 SIN	385 RCL 16	436 *	487 STO 15	537 GT0 29
283 SART	334*STO 20	386 X=Y?	437 ST- 17	488 RCL 30	538 RDN
284 ENTER↑	335 RCL 17	387 GT0 23		489 X↑2	539 2
285 RCL 35	336 COS	388 STO 23	438*LBL 26	490 XEQ "FCCDF"	540 *
286 Y↑X	337 STO 21		439 RCL 17	491 2	541 1
287 RCL 24	338 STO 22	389*LBL 22	440 2	492 /	542 X<>Y?
288 *	339 STO 23	390 1	441 *	493 STO 00	543 GT0 30
289 RTH	340 DEG	391 ST- 23	442 PI	494 RCL 16	544 RDN
	341 1	392 RCL 23	443 /	495 STO 15	545 2
290*LBL 15	342 STO 24	393 ST* 24	444 1	496 RCL 30	546 -
291 RCL 15	343 STO 25	394 1	445 -	497 0	547 CHS
292 RCL 16	344 RCL 16	395 ST- 23	446 CHS	498 X<>Y?	548 RTH
293 /	345 X=Y?	396 RCL 23	447 RTH	499 GT0 27	
294 RCL 17	346 GT0 21	397 ST/ 24		500 RCL 00	549*LBL 29
295 *	347 2	398 X=Y?	448*LBL "FCCDF"	501 1	550 RDN
296 1	348 -	399 GT0 22	449 XEQ "FCCDF"	502 -	551 1
297 +	349 STO 14		450 1	503 CHS	552 -
298 1/X		400*LBL 23	451 -	504 RTH	553 CHS
299 RTH	350*LBL 19	401 RCL 21	452 CHS		554 RTH
	351 RCL 14	402 ENTER↑	453 RTH	505*LBL 27	
300*LBL 16	352 RCL 25	403 RCL 16		506 RCL 00	555*LBL 30
301 CF 01	353 X=Y?	404 Y↑X	454*LBL "BINF"	507 RTH	556 RDN
302 FS? 02	354 GT0 20	405 RCL 20	455 STO 00		557 RTH
303 GT0 10	355 2	406 *	456 1	508*LBL 28	
	356 ST+ 25	407 ST* 24	457 +	509 RCL 30	558*LBL "DMS"
304*LBL 17	357 RCL 21	408 RCL 16	458 STO 35	510 GT0 "ZCDF"	559 RCL 47
305 RCL 16	358 X↑2	409 1	459 2		560 RCL 37
306 STO 10	359 RCL 24	410 STO 26	460 *	511*LBL "CI"	561 -
307 RCL 15	360 *	411 STO 27	461 STO 15	512 RCL 32	562 STO 40
					563 END

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